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WASHINGTON UNIVERSITY IN ST. LOUIS

University College

International Affairs

The Space to Lead

by

Mack A. Bradley

A thesis presented to the
Graduate School of Arts and Sciences
of Washington University in
partial fulfillment of the
requirements for the degree of
Master of Arts

August 2013

St. Louis, Missouri

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Brendan Curry, vice president of Washington operation for the Space Foundation, and J. T. Jezerski, currently staff to the House Science, Space and Technology Committee--both of whom have deep experience with space policy--provided crucial resources and a better grasp of the politics involved in forming space policy. Meeting with Julianne Sullivan, staff director at the House Committee on Education and the Workforce and a space policy expert, was a turning point in my thinking on this project. She helped me to ask more strategic questions and to understand the decision process that led to the International Space Station which greatly expanded my investigation. Crucially, she also turned me on to the comments of Dr. Michael Griffin, a former NASA administrator, which greatly expanded my understanding of the complexities of “commercial” space. David Patterson, managing director at Castlebridge Keep consultancy, provided an appreciation of the role of soft power and the need to inspire the public. Dr. Phillip Metzger, a planetary scientist at NASA, gave me first-hand insights on the international nature of planetary science and the commercialization of technology. This last point was also picked up by Dr. Paul G. Kaminski, chairman of the Defense Science Board, US Air Force Colonel (Ret.), former Under Secretary of Defense for Acquisition and Technology, former official in the National Reconnaissance Office and Air Force Systems Command, and former Director for Low Observables Technology. He was awarded the National Medal of Technology by President George W. Bush in 2006. Dr. Kaminski provided far more insight than I could give voice to within the confines of this paper. He made the important connection between space and cyber, and really helped me to understand the destructive nature of dramatic policy shifts to space related industries among many other things. My conversation with General Kevin P. Chilton (Ret.) was equally illuminating. Gen. Chilton piloted two Space Shuttle flights, STS-49 and STS-59 and commanded Space Shuttle Atlantis STS-76. He has 704 total hours logged in space. He was commanding officer, Air Force Space Command and commanding officer, United States Strategic Command, among other duties. He is a member of the United States Astronaut Hall of Fame among many other honors. Gen. Chilton contributed his tremendous expertise

and knowledge of the orbital debris problem, the political realities of moving beyond Low Earth Orbit and the military realities of operations in space going back decades among many other things.

All of these experts were generous with their time and insightful with their commentary, so much so that I was unable to include all of it in the confines of this particular project. I deeply appreciate their contributions and more importantly their service to the furtherance of spaceflight and to the United States. Any failings of this paper to fully understand, effectively analyze and realistically opine is mine alone and no reflection on them or their perspicacity.

In addition, my family, particularly my son Devin and daughter Grace, have offered consistent and unflagging support which has seen me through the ups and downs of a far larger research and writing task than I had ever before attempted. The same is true of a legion of friends, too numerous to name. Their indefatigable encouragement kept me going through the process.

Finally, my thesis director, Dr. Andrew Sobel, and his work on Hegemonic Stability Theory focused my thinking and helped me to achieve a key insight whose progeny can be found throughout this paper.

My sincere thanks to them all.

Mack A. Bradley

August 2013

DEDICATION

This paper is dedicated to the following men and women:

Vladimir Komarov
Soyuz 1

Georgi Dobrovolski
Viktor Patsayev
Vladislav Volkov
Soyuz 11

Roger Chaffee
Virgil “Gus” Grissom
Edward White II
Apollo 1

Greg Jarvis
Christa McAuliffe
Ronald McNair
Ellison Onizuka
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Rick D. Husband
William McCool
Ilan Ramon
Columbia STS-107

ABSTRACT OF THE THESIS

The Space to Lead

by

Mack A. Bradley

Master of Arts

Washington University in St. Louis, 2013

Professor Andrew Sobel, Chair

The security and the economic health of the world, most of all the United States, have never been more dependent on outer space. Space-based systems have become critical to many nations. Public and commercial services, agriculture, finance, communications, navigation and all manner of military operations now depend on assets flying beyond the Kármán Line, the commonly accepted 62-mile-high threshold of space. In effect, the nations of the world decided decades ago to place part of their critical national infrastructure in space. Despite this, space assets have never been at greater risk, as Low Earth Orbit becomes ever more crowded. Other threats from space also loom.

Some problems threaten sustainable space activity and national security, while some could pose existential threats to whole cities or in the worst case, to human civilization--notably, the hazard of human-made orbital debris, and the need to create greater space situational awareness in the near-Earth area and a planetary defense from near-Earth objects. What might be an historically narrow opportunity to become a multi-planet civilization also factors into these problems. Dealing effectively with all these issues will depend on marshaling sustained resources, which will require public understanding and support. It will also depend strong international leadership, or it will suffer from a lack of it. In Apollo, the Shuttle and the International Space Station the United States has demonstrated both the audacity for big ideas and the capacity to realize them. To face the challenges ahead, these qualities will be required in abundance.

This paper will examine the three key decisions that shaped the American manned space program, Apollo by Kennedy, the Shuttle by Nixon and the space station by Reagan, along with the international context that made each possible. We will also examine the bipartisan US leadership that led to the first efforts to internationalize space, creating the United Nations Committee on the Peaceful Uses of Outer Space (COPUOS). We will go on to look at the growing importance of space to life on the ground, a primer on the space economy in 2013, the growing status of what has been (inaccurately) dubbed the commercial space sector, problems with the American manned space program, the Russian launch program and then the national security aspects of space. With this context, we will survey two of the

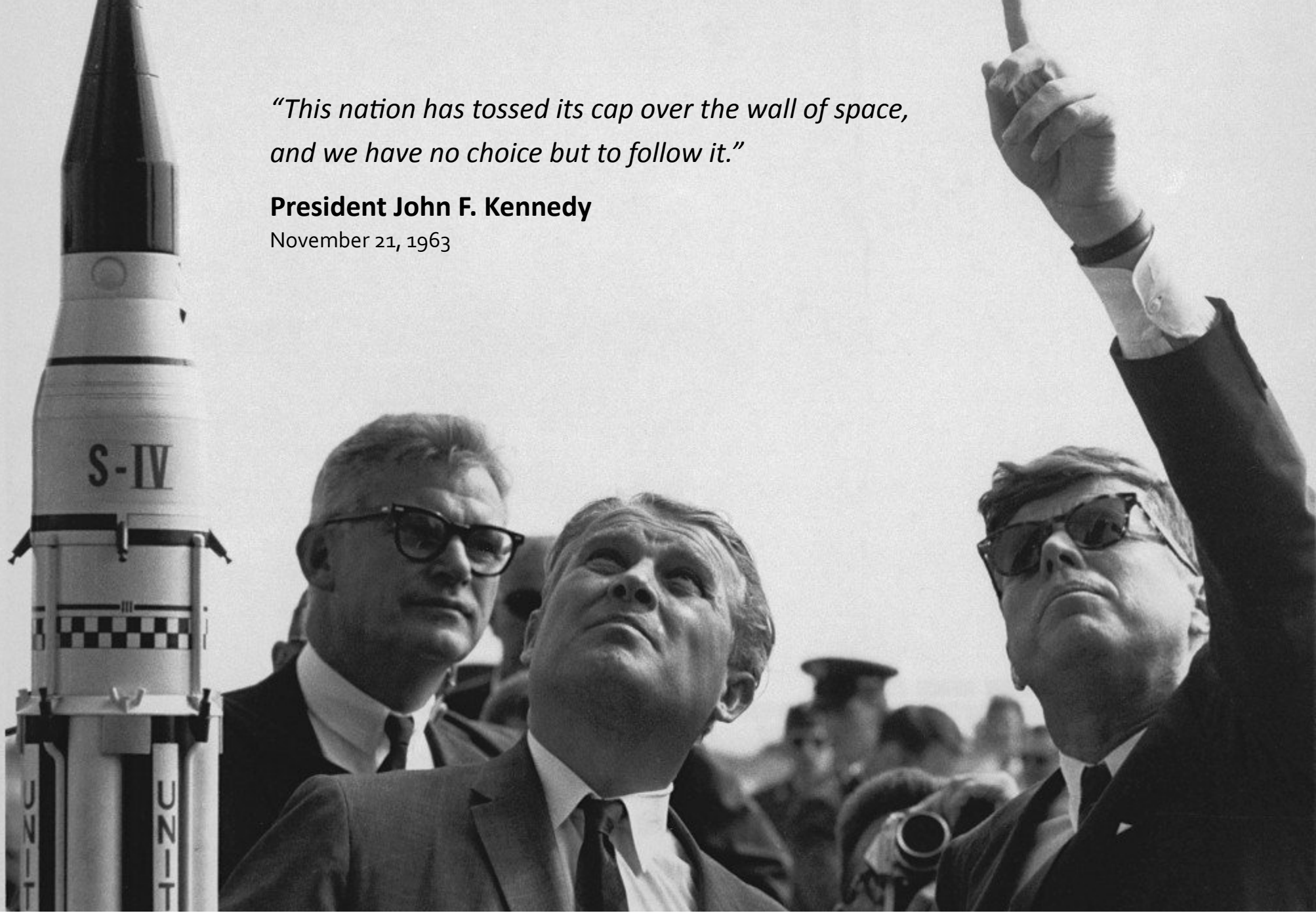
threats the international community must face down in space: orbital debris and the threat of Near Earth Objects. A third issue, human spaceflight beyond Low Earth Orbit, is an opportunity to be seized that satisfies humanity's quest for knowledge and exploration, and also mitigates against the threat of human extinction. Finally, we will outline conclusions and recommendations for leading a coordinated international response to space security threats, secure space as a safe, peaceful, cooperative arena and take the next steps in human spaceflight.



*“This nation has tossed its cap over the wall of space,
and we have no choice but to follow it.”*

President John F. Kennedy

November 21, 1963



President Kennedy, right, with Dr. Wernher von Braun at Cape Canaveral, 1961

Credit: NASA

1

LEADING FROM BEHIND

On May 25, 1961, a joint session of the US Congress witnessed one of the Cold War’s most iconic moments. President John F. Kennedy stood at the rostrum of the US House of Representatives and delivered a “Special Message to the Congress on Urgent National Needs.” The president was barely four months into his term. He had already delivered his first State of the Union message at the end of January. On this day, Kennedy noted that presidential addresses to Congress were traditionally an annual affair. But, Kennedy said, “These are extraordinary times.”

Just twenty days earlier, at 9:35 a.m. on May 5, US Navy Captain and Mercury Seven Astronaut Alan Shepard rode his Mercury-Redstone rocket from Launch Complex 5 at Cape Canaveral Air Force Station, Florida to an altitude of just over 116 miles. Fifteen minutes later, his Freedom 7 spacecraft splashed down in the Atlantic. The flight made Shepard the first American in space, but not the first human. The exploits of Soviet Air Force Major Yuri Gagarin and his Vostok spacecraft on April 12 had seen to that.

Before the Congress, the president first talked about Latin America, civil defense, disarmament and Vietnam. But his address would not be remembered for any of this. It would instead go down in the history of the Cold War as Kennedy's "moon speech."

Acknowledging the emphasis his administration had already put on space, Kennedy said America needed to do more. "Now it is time to take longer strides--time for a great new American enterprise--time for this nation to take a clearly leading role in space achievement, which in many ways may hold the key to our future on Earth."

He openly acknowledged that the Soviets had "many months lead-time" in space. But this was not because America didn't have the capacity to lead. It simply had lacked the will. "The facts of the matter are that we have never made the national decisions or marshaled the national resources required for such leadership." He asked Congress for the money to develop nuclear rockets and accelerate the development of communications and weather satellites. But first, there was a more important, more breathtaking goal to set.

"I believe that this nation should commit itself to achieving the goal, before this decade is out, of landing a man on the moon and returning him safely to the earth," the president said in the line that would make this speech famous. "No single space project in this period will be more impressive to mankind, or more important for the long-range exploration of space; and none will be so difficult or expensive to accomplish."

The president was partly right in his assessment of the effects of a manned moon landing. It was, for example, extraordinarily difficult and expensive, and it did, eight years later, unite humankind for a

brief and unique moment in all of our history. But in 1961, the proposal was bold in the extreme, coming as it did at a time when the United States could boast a mere fifteen minutes of manned spaceflight, all of it belonging to Shepard.

In a warning that is as relevant in the 21st Century as it was in 1961, the president cautioned the Congress against timidity and incrementalism in such an expensive and wide-ranging endeavor. “If we are to go only half way, or reduce our sights in the face of difficulty, in my judgment it would be better not to go at all... because it (the moon program) is a heavy burden, and there is no sense in agreeing or desiring that the United States take an affirmative position in outer space, unless we are prepared to do the work and bear the burdens to make it successful.”¹

But daring as this call to action was, it was a product of *Soviet* leadership, and the fear it generated in the West, not American leadership. Project Apollo triumphed, but it was eventually canceled after the Soviets made it clear that Cosmonauts would not be following in America’s lunar footsteps.



Audio: Kennedy’s “moon speech,” May 25, 1961.
Credit: NASA

Sitting in the Oval Office two months before his message to Congress, the contrast in Kennedy’s attitude was striking. His predecessor, President Dwight Eisenhower, had mothballed the design studies needed to launch NASA’s long-range plans, drafted in 1959, which included the development of monstrous new rockets, the Saturn and Nova family of boosters, along with a new spacecraft and a permanent near-Earth space station to serve as a jumping off point for lunar exploration sometime after 1970. The latter two elements, the spacecraft and space station, were already being called Project Apollo inside NASA. In March 1961, James Webb, the NASA Administrator and George Low, Chief of the Manned Space Flight Office met with the new president to secure his approval for the development of the Apollo spacecraft and rockets. Webb didn’t mince words. He told Kennedy that unless the president approved NASA’s plans, “the Russians will, for the next five to ten years, beat us to every spectacular exploratory flight.”²

It was hardly an idle threat. The Soviet Union had orbited Sputnik, the world's first artificial satellite, on October 4, 1957. A month later, it launched a larger version, with a dog-Cosmonaut on board. The deep concern this generated in the United States was profound and widespread. It led to, among other things, the transformation of the National Advisory Committee on Aeronautics into the more technically and bureaucratically muscular National Aeronautics and Space Administration (NASA).³ Even so, while Kennedy listened carefully, he was unmoved by Webb and Low. The next day, he decided to shelve NASA's long-term vision and the Apollo spacecraft, as Eisenhower had, but he did green-light the development of new rockets. Events, however, would force his hand.

Everything changed 19 days later on April 12, 1961, when Gagarin became the first human in space and the first to orbit the Earth. It was a stunning display of Soviet scientific and engineering prowess, and a feat that the United States would be unable to match for nearly a year. Kennedy was on the spot. He called Webb back for another meeting, this time with a substantially more urgent tone. "Is there anyplace we can catch them? What can we do? Tell me how to catch up," the president demanded.⁴ As a follow up to this, on April 20 Kennedy wrote a memorandum to Vice President Lyndon Johnson, asking Johnson to investigate several questions and report back quickly: "Do we have a chance of beating the Soviets by putting a laboratory in space, or by a trip around the moon, or by a rocket to land on the moon, or by a rocket to go to the moon and back with a man? Is there any other space program which promises dramatic results in which we could win?"⁵

NASA was skeptical that either of their previously defined goals for Project Apollo, to orbit a manned space station, and to send astronauts to orbit the moon without landing on it, could be accomplished before the Russians beat America to it. NASA rocket scientist, and former SS rocket scientist, Wernher von Braun responded to the president's questions in a memorandum to Vice President Johnson on April 29. He wrote that the Soviets had already demonstrated the ability to lift many times more payload into orbit than the United States was currently capable of doing, certainly enough lifting capacity to orbit something which could be called a "laboratory in space" if the Soviets chose to do so. Von Braun thought the US had a "sporting chance" of orbiting a 3-man crew around the moon before the Soviets. But, he said, "we have an excellent chance of beating the Soviets to the first landing of a crew on the moon

(including return capability, of course).” What made the manned moon landing a better option, von Braun said, was that while the United States lacked the mammoth rocket required for such a mission, the Soviets very likely lacked it, too. In an even race, and with an “all-out crash program,” von Braun thought the US could beat the Russians to this “obvious next” prize.⁶

Thus NASA looked down the road as a way of redefining a race they thought America could win. It was hugely ambitious. Even within NASA, there were doubts. Webb was a veteran of federal budgeting (he had been budget director under President Truman) and he worried that the sustained effort that would be required was untenable.⁷ Others shared his concerns. When the president made the plan public, future NASA flight director Glynn Lunney remembered that “I was floored, stunned, staggered by the scale of the challenge.” Future astronaut Jim Lovell (of Apollo 13 fame) was more direct: “This president must be crazy. How can we possibly do that in nine years?”⁸ Regardless of any doubts or concerns, Apollo had been recast. The space station was off the table, as was the plan to orbit the moon after 1970. Instead, the program would now aim for a manned lunar landing in a shorter time frame.

It seems clear that with Yuri Gagarin lighting up headlines around the globe, Kennedy’s appetite for risk had changed. Although the United States had yet to even send a human being into space at all, to



President Kennedy, center, attends a briefing at Cape Canaveral in 1962 with Vice President Johnson, far left, and Defense Secretary McNamara, far right. Credit: NASA

say nothing of orbiting the Earth as Gagarin had done, Kennedy was prepared to announce that Americans would visit the moon and return safely by the end of the decade. Less than a month after Gagarin’s flight, Alan Shepard completed his 15-minute sub-orbital flight, a substantial achievement to be sure but a far cry from

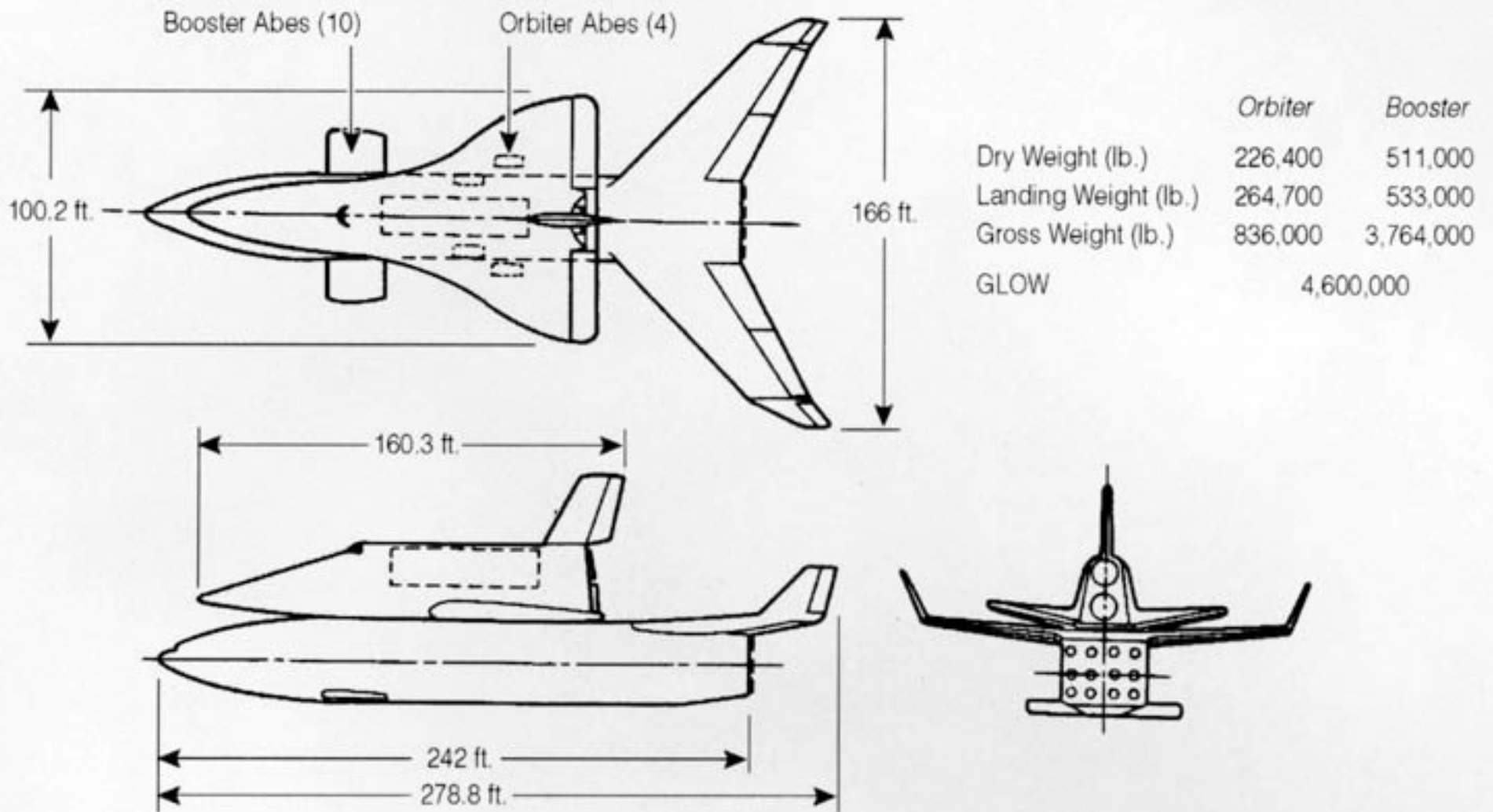
Gagarin's orbital triumph. On May 25, Kennedy told the Congress that "while we cannot guarantee that we shall one day be first, we can guarantee that failure to make this effort will find us last."⁹ The following year, in another meeting with Webb where the NASA administrator tried to discuss the scientific aspects of the moon program, Kennedy dismissed outright the notion that the space program was, or even should be, about anything other than Cold War geo-political advantage. "This (the space program) is important for political reasons, international political reasons, and this is, whether we like it or not, an intensive race."¹⁰

Ultimately, the first decade of America's civil space program was driven by a single, burning presidential question: "Is there any other space program which promises dramatic results in which we could win?" During this period, and for the only time to date, America's policy aspirations in space were in sync with its budget. The policymaking that led to and then sustained Project Apollo was an anomaly. NASA's political muscle and budget fell quickly back to Earth once Neil Armstrong and Buzz Aldrin satisfied Kennedy's drive for a dramatic geo-political victory in space, so it's hard to imagine that Apollo would have survived successive federal budget wars intact but for two things. First, after Kennedy's assassination, Apollo became part of Camelot--the inspired legacy of a fallen leader. Moreover, even though Apollo was clearly a reaction to the fact that America continued to lag in the space race into the 1960s, it also had the effect of framing the race in very concrete terms that were more favorable to the United States. Before May 1961, "winning" the space race could have meant any number of things. After that, and for the balance of the 1960s, it meant only one thing: "achieving the goal, before this decade is out, of landing a man on the moon and returning him safely to the Earth." Having therefore publicly defined the race in very specific terms and placed it so firmly in the context of the West's global struggle with communism, it would have been politically difficult for America to back off the game. In combination, these two factors sustained the program throughout the tumultuous 1960s. They even enabled it to weather the tragedy of Apollo 1, when rookie astronaut Roger Chaffee, veteran Ed White (the first American to walk in space), and Virgil "Gus" Grissom (the second American in space and surely on NASA's short list to be the first man on the moon) died when a fire swept through their capsule during a test at Kennedy Space Center in 1967.

Winning the East-West competition trumped all opposition and conquered all setbacks. It would continue to loom large in the formation of American civil space policy for the next 20 years after Apollo, but never again with such intensity. Its expression in various forms by Eisenhower, Johnson, von Braun and others during the immediate period after the word “Sputnik” became part of the world’s lexicon was the catalyst for the first truly global action with regard to outer space, led by the United States. The broad outlines of America's manned efforts in space have ebbed and flowed along with the nature of its relationship with Russia and its seemingly perennial insecurity about its leadership in space and what that might say about its place in the world. In the future, space policy decisions in Washington may be driven by America's relationship with China, though they need not be. Regardless of its motives, with Apollo, and later the Space Shuttle and the International Space Station (ISS), the United States has demonstrated both the audacity for big ideas and the capacity to realize them. These qualities will be required in abundance to address the problems and seize the opportunities ahead in space.



High Cross Range System



Fully reusable shuttle of McDonnell Douglas. (NASA)

Fully reusable Shuttle concept by St. Louis-based McDonnell Douglas.
Credit: NASA

2

SHUTTLE, STATION, AND INTERNATIONAL SPACE

International cooperation in space goes back to the very beginning. In April 1958, thanks to Dr. Eilene Galloway, a defense analyst at the Library of Congress and later an aide to Lyndon Johnson, the National Aeronautics and Space Act which created NASA included language that allowed the new space agency to create bi-lateral and multi-lateral arrangements with foreign partners, giving it the ability to cooperate internationally as needed, without the requirement of formal treaties, and thus Senate approval. This flexibility would be put to good use when it came time to build the International Space Station.

Sputnik had shocked the West, and the immediate concern in Washington was determining the nature of the military threat posed by the obvious Soviet lead in space, and specifically, as von Braun had noted, the Soviets' demonstrated ability to orbit large payloads. President Eisenhower, a Republican, asked then-Senate Majority Leader Lyndon Johnson of Texas, a Democrat, to go to the United Nations and build a coalition that would work to keep humanity's thousands of years of terrestrial conflict from rising into space as well. Johnson addressed the UN General Assembly in November 1958 on behalf of the president. He said, in part, "Today outer space is free. It is unscarred by conflict. It must remain this way... We know the gains of cooperation. We know the losses of failure to cooperate... Men who have worked together to reach the stars are not likely to descend together into the depths of war and desolation."¹¹

It was a noble and worthwhile goal, and important for setting the international tone for the space age. But Eisenhower was also being canny. The United States needed to know what was happening inside the secretive Soviet Union, so he wanted to secure the freedom, through an international legal construct, to develop space-based assets--reconnaissance satellites--capable of collecting intelligence on America's rivals from beyond the Kármán Line, the 62-mile high threshold of space, an altitude unreachable at the time by any countermeasures. He therefore set about to promulgate a regime of international law that would legitimize unfettered satellite overflights.¹² The ability to have eyes in the sky beyond the Soviets' reach would become even more important after the U-2 crisis of 1960, when an American spy plane piloted by Francis Gary Powers was shot down over the Soviet Union, making it clear that spy planes could be vulnerable (although the development of the faster, higher-flying SR-71 Blackbird spy plane was also a reaction to the U-2 incident). America therefore had complex motives for internationalizing space.

The result of this US-led initiative was creation of the United Nations Committee on the Peaceful Uses of Outer Space (COPUOS) with its Legal Subcommittee and Scientific and Technical Subcommittee. It soon became clear that, in addition to addressing the concerns about creating a vast new battleground in space, the nations of the world could use space in ways that would truly benefit all humankind. Eileen Galloway, by now an adviser to Johnson on space policy, said that therefore "the role of COPUOS was to safeguard the right of people of all nations to beneficial results from space exploration by providing

assistance for research, exchange and dissemination of information, encouraging national research programs and studying legal problems arising from space exploration. Both fear and hope brought countries together in cooperation.”¹³ The Soviet Union and several other East Bloc countries refused to join COPUOS at first, though eventually they did. This very early effort to bring the world together in pursuing the peaceful uses of space also created a solid foundation for America’s claim to international leadership in space.

Through the work of COPUOS, the nations of the world have concluded five treaties with regard to space activities. The most comprehensive is the 1967 *Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies*, better known as the Outer Space Treaty (OST). Others are the 1968 *Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched into Outer Space*, also called the Rescue Agreement; the 1972 *Convention on International Liability for Damage Caused by Space Objects*, or Liability Convention; the 1975 *Convention on Registration of Objects Launched into Outer Space*, or Registration Convention; and the 1979 *Agreement Governing the Activities of States on the Moon and Other Celestial Bodies*, the Moon Agreement, which did not become effective until 1984. In addition to these, UN members, through COPUOS, have also adopted five legal principals, covering the exploration and use of outer space (1963), the use of satellites for direct television broadcasting (1982), remote sensing of the Earth from space (1986), nuclear power sources in space (1992) and the need for space to benefit all nations (1996).¹⁴

The OST is the foundation of it all. In it, Eisenhower got what he wanted. It created the basic framework for international relations in space. Its principles have suffered very few open violations to date, notably by China in 2007 (discussed in more detail later). These principles include the following:

1. The exploration and use of outer space shall be carried out for the benefit and in the interests of all countries and shall be the province of all mankind;
2. Outer space shall be free for exploration and use by all States;

3. Outer space is not subject to national appropriation by claim of sovereignty, by means of use or occupation, or by any other means;
4. States shall not place nuclear weapons or other weapons of mass destruction in orbit or on celestial bodies or station them in outer space in any other manner;
5. The Moon and other celestial bodies shall be used exclusively for peaceful purposes;
6. Astronauts shall be regarded as the envoys of mankind;
7. States shall be responsible for national space activities whether carried out by governmental or non-governmental entities;
8. States shall be liable for damage caused by their space objects; and
9. States shall avoid harmful contamination of space and celestial bodies.¹⁵

The freedom of action the OST enables for uninhibited satellite overflight across national frontiers was a major win for US space and defense policy and it ultimately benefitted all spacefaring countries in similar ways. The later use of satellites to verify arms limitation and reduction treaties, for example, and provide other confidence-building measures was all made possible by the foresight of Eisenhower and others to see the importance of space for intelligence and defense. Interestingly, years later, during the Carter Administration when the Space Shuttle was behind schedule and over budget, the program itself would be saved in part because NASA would argue that it needed the Shuttle to launch the satellites required to verify Russian compliance with the SALT II arms control treaty.¹⁶ Along the way, unfettered satellite overflights have had other benefits to peace and security, from weather forecasting to communications and many other things.

With the foundation laid at the COPUOS, President Nixon hoped to pick up the tempo of international cooperation in space and wanted to fly astronauts from other nations on the Shuttle which did eventually happen. American efforts to build a truly international partnership, specifically with Europe, around the

Space Transportation System, as the Shuttle program was formally called, were half-hearted and strained relations among the space agencies. Ultimately, the US invited the Europeans to build a laboratory, Spacelab, that could fit inside the Shuttle cargo bay for some scientific missions. It was hardly a real partnership in the Shuttle program and the Europeans knew it. The US hesitation to engage Europe in the Shuttle program as meaningful partners was driven by concerns about security and technology transfers--issues that linger still today in Washington. At the same time, NASA officials were busy trying to dissuade Western Europe from developing its own launch vehicles, without which it would be dependent on riding the Shuttle into space. Europe thought otherwise, so instead a consortium of European nations, now in the form of the new European Space Agency (ESA), built the Ariane I, a three-stage, liquid fueled expendable rocket that came on line at roughly the same time as the Shuttle. The ESA then announced that Ariane would compete with the Shuttle for commercial satellite business.¹⁷ The arrival of Ariane on the scene pressured NASA to designate the Shuttle fleet as “operational” very early in its flight program.¹⁸ It seems doubtful that Europe would have long eschewed an independent space launch capability, even had America brought its European partners truly into the Shuttle fold. During this period, in the 1970s, Western Europe was rising above the rubble of World War II and beginning to step out of America’s shadow. In a preview of the early 21st Century, senior American officials noted the potential rise of a multi-polar world and what that might mean for US power and prestige.¹⁹ The US reaction then, from a position of dominance, was to try to marginalize its allies in terms of space.



Apollo/Soyuz mission patch.
Credit: NASA

Nixon also put in motion the first real cooperation in space between the Cold War rivals. On May 24, 1972 the United States and the Soviet Union signed an *Agreement concerning cooperation in the exploration and use of outer space for peaceful purposes*. This document ultimately lead to the Apollo-

Soyuz Test Project when the final flight of the Apollo command/service module linked up with Soyuz 19 in Earth orbit, marking a supposedly symbolic end of the space race between the superpowers.²⁰ Apollo-Soyuz did some modest science, but its real purpose was political and symbolic, as was all of Apollo before it.

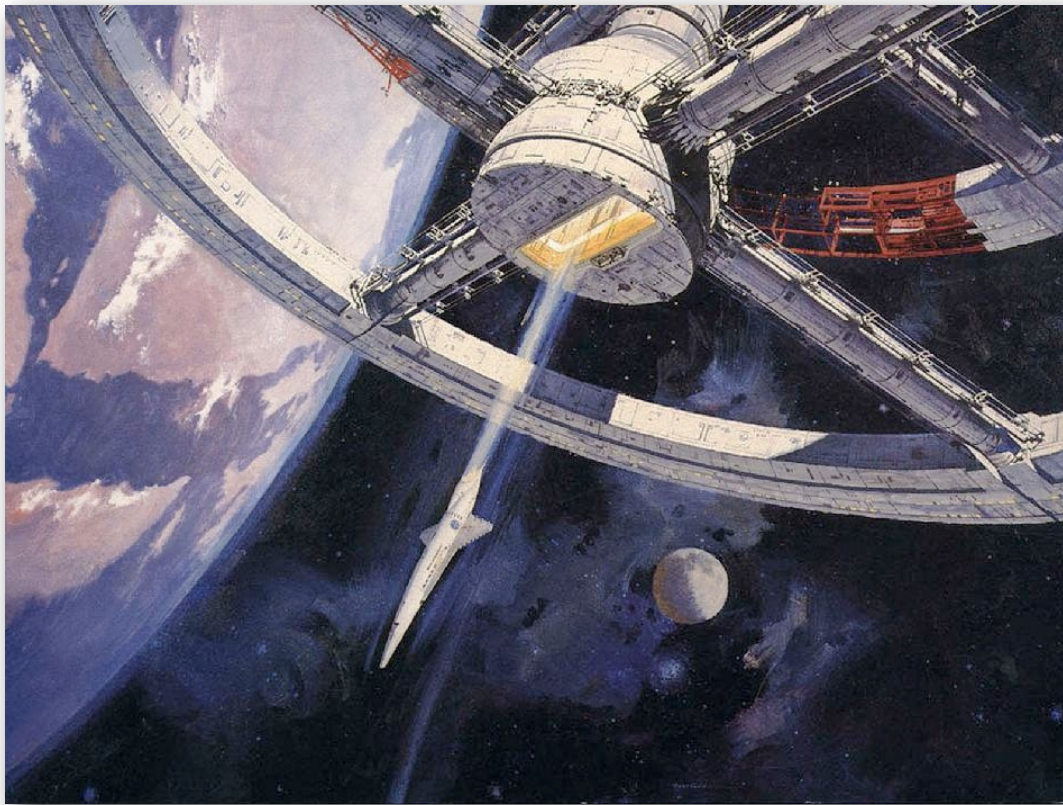
When it came time to talk seriously about a space station, the US would need to lead a real international partnership, in part because NASA was having trouble building domestic support for the station and in part because of the extraordinary costs involved. Therefore creating interest among US allies in jointly building a space station would make the station project more resilient to opposition in Washington--it gave NASA the ability to tell Congress and the administration that America's international partners were interested in this American-led project, and to imply the damage that would accrue to US diplomacy and prestige if it didn't go forward. Significantly, it also made the station project cheaper for the US at a time when deficits were seriously beginning to worry lawmakers, since some costs could be spread amongst many nations.²¹ It seems clear that given the incremental nature of NASA policymaking and budgeting in the post-Apollo era that but for the international character of the space station project as it unfolded, it quite literally would not have gotten off the ground. This was driven by a shrewd realization of that fact by key NASA officials, and President Reagan's understanding of how the station could extend American leadership and prestige in space. Whereas Kennedy's support of Apollo had been driven by a fear that America was behind in space, Reagan's support of the space station was driven by the hope of keeping America ahead. Like Apollo, scientific considerations were not absent, but were subordinate to the geo-political aspects of building the station, what that meant for US leadership in space and therefore on the ground.

The effort to internationalize the space station project began in earnest in January 1982. Kenneth Pedersen, NASA's director of the International Affairs Division called representatives from Europe, Canada and Japan to the Johnson Space Center to discuss their participation in an American space station. Initially, the conversation sounded to the US allies a lot like the Shuttle, and they were not interested in that. The Europeans in particular had new leverage, with the competitive Ariane I flying and plans in the works for heavier-lift Ariane II and Ariane III versions. Still, involvement in a US space

station was intriguing. If, and only if, it was done under the mantra of “mutual access,” meaning all partners would have access to all parts of the station regardless of which partner built it, then Canada, Japan and Europe could share in some of the high technology nourishing America’s economy. As noted earlier, some within NASA saw the effort to build international support and participation in the project mainly (or perhaps entirely) as a way to counterbalance opposition to the space station within the Congress and the administration. Others, like Robert Freitag, saw meaningful international cooperation as essential to build a station now and also for future issues in the long term. He thought it “important for us to learn to work together on a high-technology project of this scope because someday it might be really important for us to know how to work together.”²²

In the case of the space station, NASA adapted well to the post-Apollo incremental approach to building political support and a budget for such an ambitious project. Making the station international also seemed to insulate the project from the vagaries of national politics in any one partner nation--no country would want to suffer the political embarrassment of being the one to pull the plug on such a high-profile and pioneering project. Of course the space station, which Reagan would name “Freedom,” was clearly thought of as another front in the Cold War and a way of demonstrating and extending American leadership. It’s important to note, however, that although the Soviets had been orbiting a series of laboratories for a decade by this time, they were modest in scale and no effort was made to make them permanently manned. Thus, like Apollo and the Shuttle, NASA wanted to do something transformational by building a permanently manned city in space; unlike Apollo and the Shuttle, this time it needed the world to come along.

Ronald Reagan was enthusiastic about space. Industry leaders wanted him to promote the commercialization of space through subsidies and eliminating what they saw as unfair commercial satellite launch competition from the Shuttle--they would have fit right in in 2013. But the one thing that would do the most to promote commercial space, said the heads of eleven US companies invited to meet with Reagan in 1983, was a space station. Nonetheless, Reagan was wary about a Kennedy-style commitment during a time of daunting budget deficits. He knew from his earliest days as president that NASA saw a space station as the next logical step in space exploration. On April 11, 1983, Reagan signed



The rotating, or “pinwheel” space station design never got off the ground. This painting, from a promotional poster for the film *2001: A Space Odyssey* shows a rotating station, similar to von Braun’s concepts. Credit: Robert McCall/MGM, courtesy of NASA

National Security Decision Directive 5-83, to create an inter-agency study of plans for a permanently manned station. NASA formally presented the space station to Reagan and members of his cabinet on December 1, 1983. Four days later, after the NASA administrator and the director of the Office of Management and Budget wrangled about the cost, the president endorsed the idea. Six weeks after that he was standing at the rostrum of the

US House of Representatives, where John Kennedy had sent America to the moon 23 years earlier. “I am directing NASA to develop a permanently manned space station and to do it within a decade,” he said.²³

The space station “Freedom” project languished during the rest of the 1980s however, as budget pressures diminished its ambitions, the Cold War thawed and the waning competition with Moscow seemed also to subdue appetites in Washington for a hugely expensive project like the station. The larger and far more expensive “pinwheel” space station concept had long since given way to a modular chain of “tin cans.” Then the Soviet empire collapsed, and the situation was again transformed. Daniel Golden, NASA Administrator under President Bill Clinton presided over the opportunity to bring the new Russian Federation into the task of building a space station. Like Apollo-Soyuz, it would also be highly symbolic--instead of Space Station Freedom orbiting the Earth as a stick in Moscow’s eye, the International Space Station would tie Russia and the West together in a lasting way, at least in space. So on November 7, 1993 the United States and Russia signed an agreement to bring Moscow into the space station fold. Much like Eisenhower’s decision to internationalize space and promote peace among the stars, the decision to invite the Russians to what was now the ISS project was more complex than

pursuing post-Cold War niceties. It involved, for example, an effort to bring Moscow into compliance with the Missile Technology Control Regime, a voluntary international agreement to control the export of weapons of mass destruction.²⁴

Following the addition of Russia to the ISS family, the first module of humanity's first city in space was launched by a Russian Proton rocket in 1998. The outpost was deemed complete in 2011, after the final Shuttle flight, Atlantis STS-135, delivered two logistics modules. It is today by far the largest object in Earth orbit and home, currently, of the Expedition 36 crew made up of six people from three nations. According to NASA, the station "spans the area of a U.S. football field, including the end zones, and weighs 924,739 pounds. The complex now has more livable room than a conventional five-bedroom house, and has two bathrooms, a gymnasium and a 360-degree bay window."²⁵ Consisting of modules built on the ground by different nations at sites thousands of miles apart and then fitted together with extraordinary precision for the very first time on orbit at a cost of more than \$150 billion, the ISS is also the single most ambitious and expensive object ever created by humans. It is all the more remarkable since the resources and level of coordinated effort applied to it by many nations are on a scale more commonly associated with the waging of war.

The ISS has been continuously occupied since Expedition 1, made up of two Russian cosmonauts and one American astronaut, docked with it in 2000. With America's inability to launch human-rated spacecraft for the moment, only Russia's venerable Soyuz spacecraft are capable of ferrying people to and from the station (since China, the other manned spaceflight-capable nation, is not a party to the ISS).

When the time came to take on such an immense task, NASA's ability to create multi-lateral agreements with other countries, a product of Eileen Galloway's prescience in 1958, made possible the international partnership framework that built the ISS. This same framework, and the years of close cooperation built up among the member space agencies, could serve as a strong foundation for other collaborations that allow humanity to address the major problems identified in this paper, but also to take the next essential steps in human and robotic exploration. Until the early 21st Century, each step of

major international cooperation in space has been led by the United States, always with the strengthening of US global leadership in mind. It remains to be seen if that leadership will continue.

The space and space policy environments have again evolved. The US Department of Defense recognized this in a directive issued in October 2012, saying that space was “ increasingly congested, contested, and competitive.”²⁶ In response to many issues like orbital debris, commercialization and concerns about the “militarization” of space, the international community has been casting about for solutions to problems new and old. The 2010 US National Space Policy (NSP), for all its faults which are discussed later, does take a broad international view, seeking to “Expand international cooperation on mutually beneficial space activities to: broaden and extend the benefits of space; further the peaceful use of space; and enhance collection and partnership in sharing of space-derived information.”²⁷

China and Russia have since February 2008 pursued in the United Nations Conference on Disarmament a new binding treaty called *The Treaty on Prevention of the Placement of Weapons in Outer Space and of the Threat or Use of Force Against Outer Space Objects* (PPWT). In 2005, the legal subcommittee of COPUOS took up the issue of creating a “Definition and Delimitation of Outer Space.” Both have been opposed by the United States. In the matter of defining outer space, the US delegation essentially testified that the proposal was a solution in search of a problem. “The current framework has served us well and we should continue to operate under this framework until there is a demonstrated need and a practical basis for developing a definition or delimitation,” said Kenneth Hodgkins, the US delegate.²⁸ As for the proposal for a new binding treaty, the United States has dismissed the idea as unverifiable and unnecessary. The binding treaty proposal is further hampered by the difficulties of defining space weapons. General Kevin P. Chilton (Ret.), a former astronaut and former commander of both US Space Command and US Strategic Command, puts the difficulty in creating such a definition starkly. “If you built a spacecraft that could maneuver in space and fly up next to another satellite and you put robotic arms on this thing so that it could reach out and grab that satellite, would you consider that a weapon?” he asks. “Well, I flew in one of those things. It’s called a Space Shuttle.” Furthermore, the apogee of an Intercontinental Ballistic Missile is some 600 nautical miles, well into space--the

significance of this is that for decades, many countries have developed missiles which if used would necessarily transit through space en route to their targets.

As for the overall militarization of space, Gen. Chilton says that conversation is a bit late: “That boat sailed in about 1960.” There are, he says, “assets in space that are used to support military operations, whether that be GPS, communications satellites or early warning infrared missile detection satellites. They’re not up there for civil use.”²⁹

American opposition the PPWT has a long historical pedigree. In the 18th Century, Britain’s Royal Navy ruled the waves and thus London opposed attempts to bind all nations through international law on the seas. During this time, the great champion of new international rules on the world’s oceans was the United States. The reasons apply today as much as ever. Stronger powers in a particular realm, in our case outer space, fear being constrained more than they fear lawlessness. It is simply not in the interests of the United States to support a binding treaty as proposed by China and Russia because it remains the more capable, relatively stronger power in this domain.³⁰ Less capable powers want to use the law to reign in those with more capability and in so doing level the playing field, giving them protection against the greater capabilities of others and buying them time to catch up. When the US set in motion the process that would become COPUOS and the OST, it feared Soviet dominance in space. As the relative US edge in space narrows, such constructs may become more attractive but for now, US opposition has left the treaty proposal to languish in the Conference on Disarmament. This, in turn, has stalled other efforts before the Conference, including work on an agreement related to orbital debris.³¹

In an effort to bridge the gap, Europe has put forth a compromise position called the *Code of Conduct for Outer Space Activities*, which would be a non-binding convention designed to build the kind of transparency and confidence building measures (TCBMs) also called for in the 2010 NSP. Part of the draft Code takes direct aim at China, saying that all states should “refrain from the intentional destruction of any on-orbit space object or other activities which may generate long-lived orbital debris.” It also calls on spacefaring nations to share information about practices and policies, as well as a call to abide by all existing space treaties, which the Code enumerates.³² US Secretary of State Hillary Clinton

announced American support for the Europeans' non-binding approach in January 2012.³³ Regardless, it will take some time to work through the myriad of issues related to such a Code and as of this writing, China and Russia continue to push for PPWT with more teeth. The difficulties of defining terms and verifying compliance with a binding treaty are significant and would certainly take far more time to work out, even with US support of the idea, which is unlikely without some significant change in the international situation. Moreover, a combination of the existing tapestry of binding space treaties, and Europe's aspirational Code of Conduct is a sound, incremental and practical approach. The United States would do well to push the matter forward with its European allies, rather than just lending tacit approval while actively engaging China and Russia.

After 40 years of intense, if peaceful, conflict, the US and Russia quickly came together on the ISS since it advanced the interests of both. Today, cooperation in space between the ISS partners is well-

established even if other aspects of their relationships are chillier. But what is for some the obvious step of including China in the ISS family is firmly off the table, at least for the moment. Not only has America opposed Chinese involvement in the ISS, but thanks to US Rep. Frank Wolf (R-Va) it's actually against the law for NASA to even cooperate with the Chinese space agency. In a 2012 meeting in Quebec City, Canada, the ISS partners discussed Chinese participation, with ESA director general Jean-Jacques Dordain voicing support for some level of cooperation with China. NASA Administrator Charles Bolden reminded his international



This commemorative plaque was presented on the occasion of the signing of the International Space Station Agreements. Credit: NASA

colleagues that his agency could not support Chinese participation in the station, but that they should pursue other forms of cooperation with China. Despite Bolden's nearly heroic efforts to thread the diplomatic needle, press reports of the meeting prompted an angry letter from Rep. Wolf. Wolf told Bolden that he "should make clear that the U.S. will not accept Chinese participation in any station-related activities."³⁴

US efforts to ice China out of the ISS, and to outlaw even the smallest cooperation with an emerging and important space power are painfully short-sighted. A bitterly Cold War didn't stop US/Russian cooperation, as early as the 1970s. The difference in American attitudes in the case of the station relates to the fact that the United States won the Cold War. In the early 1990s, Russia was exhausted, a spent force that would take years to rebuild and the US was in a position of strength. China on the other hand is rising rapidly, economically, militarily and in terms of space. Concerns about technology transfer to, or technology theft by, China are rife in the US. China didn't help themselves either in their efforts to be welcomed into the ISS community. In 2007, China's People's Liberation Army destroyed a defunct Chinese Fengyun-1C weather satellite with a ground-based anti-satellite (ASAT) missile. This intentional explosion in Low Earth Orbit (LEO) was the largest debris-generating event in the history of spaceflight, creating 2,317 pieces large enough to track, and perhaps as many as 35,000 smaller pieces according to a 2007 report by NASA's Orbital Debris Program Office (ODPO).³⁵ This unannounced ASAT test was grossly irresponsible, making a far more dangerous environment in LEO for all spacefaring nations, and it is hard to square with the principles of the OST, to which China is a signatory. A month after Fengyun, the COPUOS Scientific and Technical Subcommittee adopted a set of seven guidelines to slow the growth of orbital debris, including a call to avoid the intentional destruction of any orbiting spacecraft.³⁶

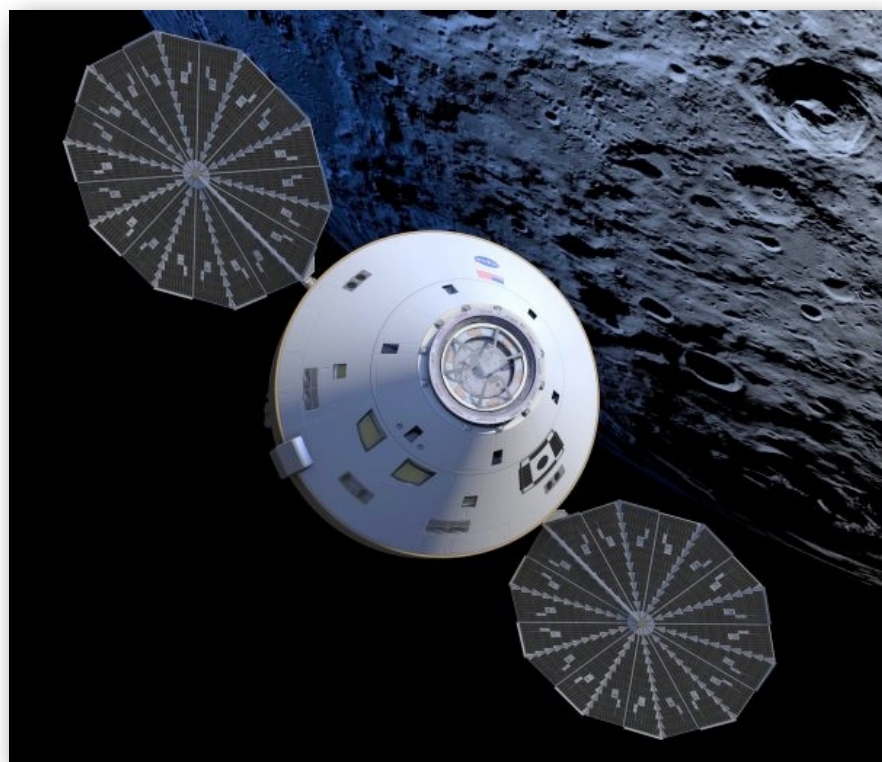
Even so, the United States entered into Apollo-Soyuz in the afterglow of the moon landings. It brought Russia into the ISS partnership from a position of strength vis-a-vis its former Cold War rival. The overall competition to come between the United States and China is too broad for the purposes of this paper, but China's rise in terms of space capabilities and aspirations will certainly continue. Barring some other sort of foolish and destructive behavior like Fengyun, it's reasonable to assume that China's international standing as a spacefaring power will continue to grow in tandem with its capabilities.

Furthermore, while an absolute and persistent decline in America's space capabilities, prestige and international leadership are by no means certain, a relative decline almost certainly is. As Dr. Paul Kaminski says, where the US once had a virtual monopoly, now the list of spacefaring countries continues to grow. Dr. Kaminski is chairman of the Defense Science Board, a US Air Force Colonel (Ret.), former Under Secretary of Defense for Acquisition and Technology, former official in the National Reconnaissance Office and Air Force Systems Command and Director for Low Observables Technology who oversaw the development of stealth technology in platforms such as the F-117 Nighthawk (popularly, and inaccurately, known as the "Stealth Fighter") and the B-2 Spirit ("Stealth Bomber"). "It was a monopoly that we could offer to share in with key allies so it had a big influence on their willingness and interest in cooperating with us on national security policy." But now, Kaminski says, things are changing "because some aspects of space are becoming more of a commodity. There are other countries now launching their own reconnaissance satellites, launching their own communications satellites, buying communications as a commodity, so our (space) policy and capabilities, while still very important, have a less sharp influence."^{36A}

Some new space powers, like China, will be large, significant players whether the United States likes it or not. It would be wise therefore for the US to engage with China from a position of relative strength. It is simply unrealistic to believe that the rest of the world will continue to ostracize China's space program simply because it suits American purposes. Right now, the most obvious point of contention is China's exclusion from the ISS partnership. But once the ISS is de-orbited, either in 2020 or sometime thereafter, the world will move on to the next project, all of the options for which lend themselves to a broad international partnership. If the US continues to snub China now, it will instead find itself having to create a working relationship with China in the future when US power and influence are likely to be relatively diminished. The technology transfer concerns among US policymakers go far beyond space, and China will accomplish its goals in space with or without technology transfer that may result from US engagement, and indeed which may result whether or not the US engages China.³⁷ Integrating China into a robust international partnership, the ISS, of which the US was the principal creator and remains a

strong leader despite the gap in US manned spaceflight seems far preferable to the US entering a future partnership which could well be of Chinese design.

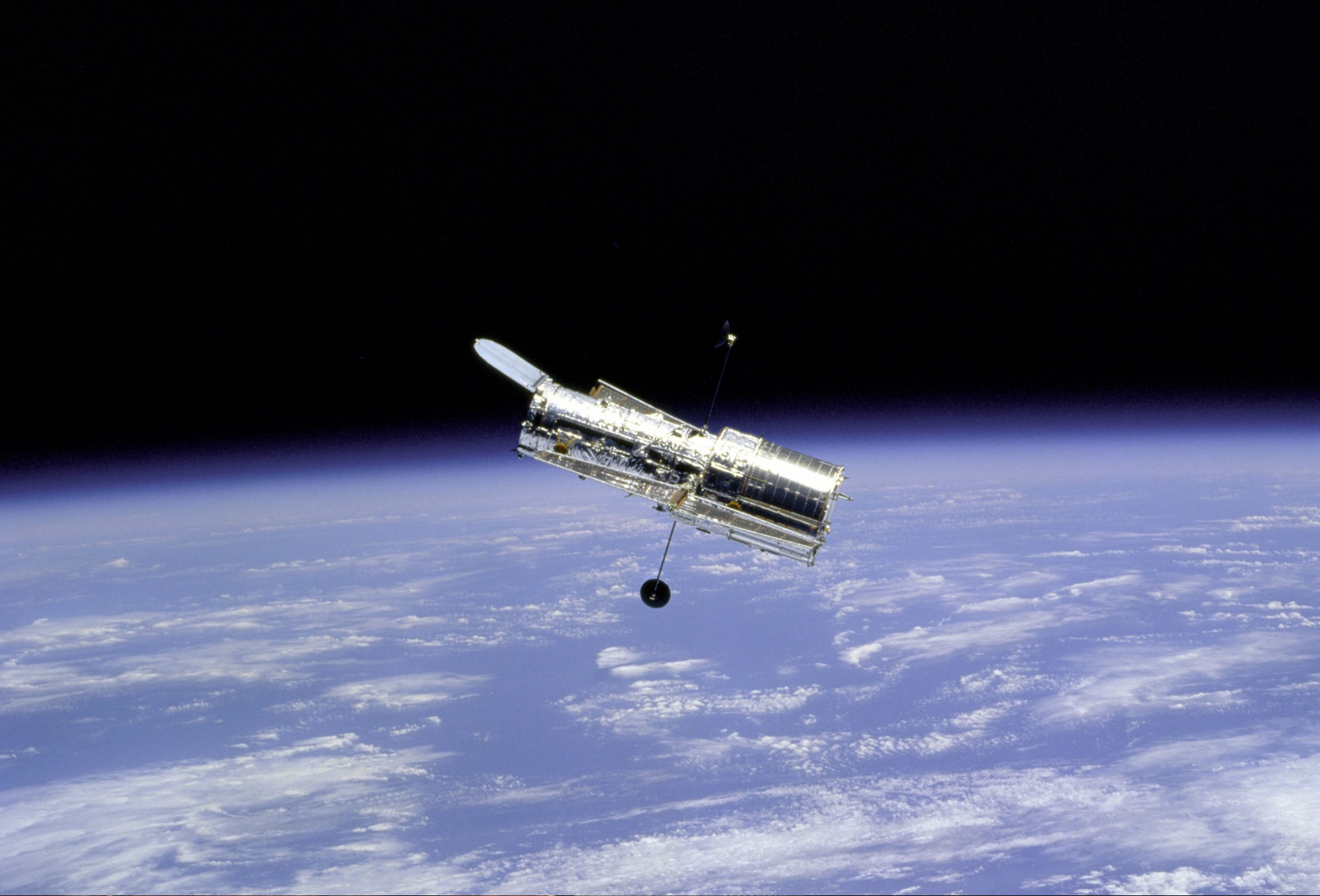
An opportunity for this kind of new cooperation exists outside the current ISS as well. The original Memorandum of Understanding that led to the ISS actually called for two space stations, one generally akin to the current ISS and a smaller one in a different orbit which was never built. This might be an opportunity to engage China and the ISS partners with a plan put forth by the Obama Administration in 2012 to build a smaller outpost at the L-2 Lagrange point on



Artist rendering of the Orion spacecraft passing the moon en route to L-2. Credit: NASA

the far side of the moon. Components left over from ISS construction as well as America's Space Launch System (SLS) rocket and Orion spacecraft (also called the Multi Purpose Crew Vehicle) could all be used. Such an outpost could play a role in NASA's plans to capture an asteroid and park it in lunar orbit and as a way-station on a trip to Mars. An amendment could be made to the ISS MOU to move this second, smaller station to L-2 rather than Earth orbit, and to include China and possibly India. An L-2 space station may or may not make sense and the politics of it remain complicated, both on Capitol Hill, where the idea of an L-2 station received a chilly reception and in other spacefaring capitals, where there remains a hope for a manned return to the lunar surface, not just lunar orbit.³⁸ Even so, beginning such discussions within the framework of the existing ISS partnership, with China included and possibly India, would provide a platform for a robust exploration of the international community's next steps in space among a more realistic group of nations without necessarily bringing new nations into the current ISS. None of it will happen so long as US law treats China's space program as if it doesn't exist.





The Hubble Space Telescope.
Credit: NASA

3

WE NEED OUR SPACE

In the 1950s, as human activity in space seemed on the horizon, Hungarian-American aeronautical engineer Theodore von Kármán worked out where to mark the edge of space, not a simple task since the atmosphere doesn't simply end at some point. Instead, it fades away and thins out as one ventures further from the Earth's surface. But Kármán had some help. Some four centuries earlier, Sir Isaac Newton had calculated the speed at which an object could be maintained in Earth orbit--orbital velocity. With Newton's shoulders to stand on, Kármán determined that above 100 kilometers (62 miles) the air became so thin that an aircraft would have to fly at orbital velocity--some 17,300 mph--to remain aloft.

This boundary, in essence the point where flight becomes spaceflight, has since been commonly known as the Kármán Line although no legal boundary of space has ever been set.

The security and the economic health of the world, most of all the United States, have never been more dependent on objects flying beyond the Kármán Line. Space systems have become part of the critical national infrastructure for many countries. Public and commercial services, agriculture, finance, communications, navigation and all manner of military operations now depend on space assets. Despite their vital importance, these assets have never been at greater risk, as LEO, where the ISS, all other manned spacecraft and most satellites fly becomes ever more crowded and dangerous. The last manned flight to reach beyond LEO was Apollo 17 in 1972.

The latest NSP published in 2010 notes that “Space systems allow people and governments around the world to see with clarity, communicate with certainty, navigate with accuracy and operate with assurance.”³⁹ Exploration and investment beyond the Kármán Line produces real terrestrial gains and as the NSP says, “life on Earth is far better as a result.” Weather forecasting, natural disaster prediction, disaster response and rescue operations, management of agriculture and other natural resource management, global finance, communications and navigation have all been transformed by our access to and use of space since the 1960s.⁴⁰ In fact, the return on investment (ROI) in space touches so many fields in so many ways that determining its precise value can be elusive. Moreover the ROI in space has changed significantly as the space age has evolved. Some benefits, like those mentioned above, are tangible, while others are more ephemeral. Many studies published from the 1960s to the 1980s agree that investment in NASA, for example, has real economic benefits. Henry R. Hertzfeld, of George Washington University's Space Policy Institute, wrote that “no one measure is a comprehensive indicator of NASA impacts and benefits. There are many things we just do better thanks to space investment, big things,” such as telecommunications, Hertzfeld said.⁴¹

A Denver Research Institute study concluded that investment in space allowed “technological advancement to occur at an earlier time than it would have occurred otherwise” if indeed it would have happened at all.⁴² A Midwest Research Institute study is more specific. Looking at the overall

relationship between research and development spending and technology-related increases in US Gross National Product (as opposed to GDP) the MRI study found that every dollar spent on R&D returned more than seven dollars in GNP over the following eighteen years. If one assumes, as MRI does, that space-related R&D spending by NASA alone (not counting military R&D) has at least the same rate of return on investment as other R&D, then the \$25 billion (in 1958 dollars) that NASA spent on the civil space program from 1959 to 1969 returned \$52 billion by 1970, and (writing in 1974) a projected \$181 billion by 1987.⁴³

Dr. Kaminski argues that America's return on investment in space technology was once significant, as the MRI study seems to confirm. Kaminski says that the Apollo program and the military rocket programs (such as the Minuteman missile) that accompanied it "drove our whole research and technology base" in the 1960s and 70s. In particular, "the quest for performance and miniaturization and the like actually created the foundation for our whole semiconductor industry." The return on America's investment in Apollo and Minuteman Kaminski concludes, was "enormous."⁴⁴

At a technical level, Kaminski notes that the situation today is also quite different. "The investments we are making in space capabilities certainly do have some spinoffs and some enablers for other applications," notably in navigation and communications. "But the spinoffs are much less. So the overall return on investment to the economy is a small part of what it was in the 60s and 70s," Kaminski says. This is largely because the technological environment today is different. Spacecraft themselves can be built with more commonplace, commercially-available components in many instances. Moreover, because of the long development time of spacecraft and the need for components to be space-rated (meaning they can survive in the hostile environment of space) compared with the overall speed of technological advancement on the ground, space assets are often fielded using technologies that are two to three generations behind the state of the art. As a result, we have, as Kaminski puts it, "progressed to the point where the spinoffs are not the same." Exceptions to this certainly exist, in apertures, optics and antenna that are not commercially available, such as those used in military reconnaissance and the Hubble Space Telescope, for example.⁴⁵

As governor of California, Ronald Reagan had seen first-hand the positive impact the space program had on technological and economic development and in 1970 he predicted that “the many uses of space technology will make our investment in space as big a bargain as that voyage of Columbus which cost \$7,000--and which was denounced as a foolish extravagance.”⁴⁶ Later, as president, he was a bit more cost sensitive though he did green-light what would become the ISS.

The list of Earthly services that now depend on satellites for the completion of every day tasks is extensive. Space has enabled the rise of truly global utilities. Arguably, there are now four global utilities: the Global Positioning System (GPS), Russia’s version of GPS, called Globalnaya Navigatsionnaya Sputnikovaya Sistema (GLONASS), the Internet and the US Air Force Space Surveillance Network (SSN). Three of the four, GPS, GLONASS and the SSN, certainly would not be possible without satellites and the SSN would not be necessary without them (which will be discussed in more detail later). GPS and GLONASS were built for military use, though civilian use of GPS has become ubiquitous. Beyond getting drivers to their destinations, civilian GPS use enables any number of other commonplace, every day functions, from helping first responders take the shortest route to an emergency, to creating safer and more fuel efficient trans-oceanic jet travel, to saving billions of dollars in fuel costs for the US trucking industry.⁴⁷

Accurate, weather forecasting, which has an obvious impact on every day life, is also crucial in protecting life and property in major storm events. The ability to track and more importantly project the path of a major storm such as Hurricane Sandy which slammed the eastern seaboard of the United States in 2012, leans heavily on satellite imagery. Satellites and the computer models their images feed allow for reasonably accurate storm predictions within about a five-day window. This warning time allows emergency response and other public agencies to take proper measures and warn the public. Absent such



Hurricane Sandy envelops the US northeast, 2012. Credit: NASA/ Getty Images

space-based resources forecasting would certainly suffer. Data shows that forecasts of the 2010 blizzard that walloped the Washington, D.C. area, for example, would have missed the mark by half without satellite data, massively underestimating the strength of the storm.^{47A}

Long before forecasting and other satellite-based services became so embedded into daily life on the ground, Associate Director of Science at NASA Ernst Stuhlinger, writing in 1970, offered his view of the Earthly benefits of space investments to Sister Mary Jucunda, a Catholic nun based in Zambia. Sister Jucunda had asked why NASA was spending money on space when it could better be used to address Earthly problems (a commonplace question in the Apollo period). He touched on the economic benefits of space-related investments, but his letter focused more on the opportunities created by humanity's move into space that he believed would extend human knowledge in a variety of fields. Stuhlinger said in part: "Besides the need for new technologies, there is a continuing great need for new basic knowledge in the sciences if we wish to improve the conditions of human life on earth. We need more knowledge in physics and chemistry, in biology and physiology, and very particularly in medicine to cope with all these problems which threaten man's life: hunger, disease, contamination of food and water, pollution of the environment..."

"As a stimulant and catalyst for the development of new technologies, and for research in the basic sciences, it (the space program) is unparalleled by any other activity. In this respect, we may even say that the space program is taking over a function which for three or four thousand years has been the sad prerogative of wars."

Stuhlinger opined that the space age provides people "with the technologies, the challenge, the motivation, and even with the optimism to attack these tasks with confidence."⁴⁸ He was certainly right that the act of rolling back ignorance has inherent benefits. Whether people use the knowledge gained for good or ill is another matter, but Stuhlinger touched on something fundamental here. It's important to remember that people living in the time of Apollo might also personally remember the Wright brothers' flight at Kitty Hawk, a mere 60 years prior. The act of achieving things that may have seemed quite literally impossible injects a sense of overall confidence that humanity's eternal suffering at the

hands of implacable foes--war, pestilence, famine and so forth--may yet be consigned to history if only we put our collective effort to it. Today, the space age has lost much of that sort of luster but it still has its moments. In 2012, Mars Curiosity's harrowing landing on the Red Planet captured the imagination, and at least 2.1 million views on YouTube. Europe's COROT and NASA's Kepler planet-hunter spacecraft have both stirred the public mind with discoveries of hundreds of exoplanets around hundreds of stars, and thousands of candidates waiting to be analyzed. Canadian astronaut Chris Hadfield became the closest thing to a space rock star in 2013 during his tenure as commander of ISS Expedition 35, using social media to give the public a sense of life on the station and even producing (with the help of the Canadian Space Agency) his own music video rendition of David Bowie's *Space Oddity*, viewed nearly 17.5 million times on YouTube.

The entire space environment, both the political environment on the ground and the physical environment above the Kármán Line, has changed dramatically in the last fifty years. One thing, however, is certain: humanity has crossed the celestial Rubicon. Barring cataclysm, a collapse of civilization or gross negligence, a comprehensive retreat from space is most unlikely. Of those three, negligence seems at the moment to pose the greatest threat, fed by a public that understands little about how important space assets are and how difficult and expensive it is to operate safely and effectively in the harsh environment of space. LEO is not only becoming more crowded and dangerous, but it has permanent residents. Just as the first steps into space paid dividends in economic, technological and social terms, any program of continuing exploration and utilization of space would have to do the same. America's next moves toward a new capability for human exploration beyond LEO should have clear advantages to the United States said the Review of U.S. Human Spaceflight Plans Committee, better known as the "Augustine Commission," so named after its chairman, Norman Augustine. "This (human spaceflight beyond LEO) should carry important benefits to society, including: driving technological innovation; developing commercial industries and important national capabilities; and contributing to our expertise in further exploration."⁴⁹ Identifying these benefits will be critical for making the case to taxpayers and lawmakers during what will surely remain a tight budget environment in Washington. Even in the halcyon days of Apollo and the economic growth of the 1960s, public appreciation for the

economic and technological growth driven by space investments was modest. Polls have consistently shown, true even at the time that Armstrong and Aldrin were suiting up for their mission, a majority of Americans support space exploration, though the percentage always drops into the 40s when they are reminded that these things cost money. Even so, Americans seem to think that Apollo looks like a better deal as it recedes into history (and they are further removed from its actual costs). An ABC News report on the 40th anniversary of the first lunar landing said that “Since 1979, the number of people saying the moon landings were worth the cost has risen from 41 percent to 65.”⁵⁰





A satellite from Europe's planned Galileo Global Navigation Satellite System.
Credit: ESA

4

ECONOMY OF SPACE

Having looked at the overall reasons why space is important to life on the ground, and whether investments in space pay off, an overview of spending in this arena and some of its major components is appropriate. In 2012, the global space economy represented more than \$300 billion, or .0004% of the estimated \$72 trillion gross world product.⁵¹ This modest figure does not account for all the economic activity that depends on services provided by satellites or any multiplier effect of space spending. The largest share of the space economy, \$116 billion, is made up of space-based commercial products and services. Ground-based commercial infrastructure to support space makes up another \$110 billion. The

largest space-based components are direct-to-home television satellites (such as DirecTV or Dish Network in the United States), satellite communications (broadcast television and mobile phones, for instance) and satellite radio (SiriusXM, for example).

Government spending on space varied widely across the globe in 2012. Total US government spending on space was larger than all other nations combined. Even as the Space Shuttle program wound down, the US government spent nearly \$48 billion on civil and military space activities. The largest share of this total was Department of Defense spending at \$27 billion, followed by NASA at \$18 billion and the National Oceanic and Atmospheric Administration at \$2 billion. The balance of less than \$1 billion is funds space related activities for the National Science Foundation, US Geological Survey, Department of Energy, Federal Aviation Administration and Federal Communications Commission. The other nations of the world combined spent a total of nearly \$9 billion on military activities. Non-military government spending on space outside the US was lead by the European Space Agency, with a budget of just over \$5 billion, followed by the Russian Federation with \$4.5 billion. China and Japan spent more than \$3 billion each, while India and France came in at just over \$1 billion each. All other nations make up just over \$3 billion combined in civilian space spending. When non-US military space spending is included, the total 2012 spend by non-US governments in space accounted for \$30.5 billion.⁵²

Eleven nations currently have the ability to launch an unmanned vehicle into space, while only two, the Russian Federation, and the People's Republic of China are capable of flying people into space. Sixty countries and companies own and operate the approximately 1,100 active satellites on orbit that play a role in every day lives on the ground. ⁵³ The commercial space products sector grew by 6.5% from 2011-2012, while the ground-based infrastructure and support sector grew by 11% over the same period, the largest segment of growth in the space economy.

Although this ground-based segment includes large scale applications like launch services, most of its growth was in the sales of global navigation satellite system receivers, such as those in millions of cars, smartphones and other products. The majority of these were GPS receivers, though some were also designed to integrate with GLONASS. GPS and GLONASS are currently the only two operational global

navigation satellite systems, although China is extending the reach of its regional BeiDou navigation network into a global system. The European Union has also begun the deployment of its global Galileo system, although this is well behind schedule.⁵⁴ BeiDou and Galileo may be operational on a global scale by 2020. GPS was originally built for use by the US military and only later became commercially available, but given how quickly and deeply GPS has embedded itself in daily life, Europe's Galileo is being designed specifically for commercial use while GLONASS and BeiDou will both be available to the public in addition to military uses.⁵⁵

Other European and Asian countries have plans for regional systems of this type; on July 2, 2013, India successfully launched the first element of its Indian Regional Navigation Satellite System atop an Indian Polar Satellite Launch Vehicle-C22.⁵⁶ The ability of millions of consumers to determine their precise global location at any time, either in their vehicles or via a hand-held device has implications for products and services that have only begun to be explored. In any case, it is a telling reminder of how much space technology is integrated into the daily lives of millions. Even before commercial GPS, global live broadcast television, radio and telephone communications were all made possible by spaceflight.

Although a smaller monetary piece of the space economy, space launch operations obviously remain essential and that market, too, is becoming more crowded and competitive. Russia remained the world's busiest launch operator in 2012, both on the commercial and non-commercial side, with 7 commercial and 17 non-commercial launches. China came in second, with 2 commercial and 17 non-commercial launches and the United States third with 2 and 11, respectively. Others attempting orbital space launches were Iran, India, Japan and North Korea with 9 combined non-commercial launches. SeaLaunch, a multinational commercial operator conducted 3 commercial launches from its ocean-based launch platform called Odyssey.⁵⁷

Worldwide, 119 new satellites were placed on orbit during the year. The majority of them, 41, were new communications satellites. Technology demonstrators made up the second largest group, 29, followed by satellites for remote sensing and environmental monitoring, 23, scientific research, 10,

navigation, 9, and reconnaissance, military communications and early warning platforms, 7.⁵⁸ These newcomers joined a constellation of more than 1,000 active satellites already on orbit.

Twenty-five spaceports are in operation around the world as of 2012. The United States leads the field with eight operating spaceports, seven orbital and one public, sub-orbital. Russia and China each operate three. Four more are in some stage of development in the US and another four are proposed, most of them public. Some of the proposals involve creating spaceports adjacent to or nearby commercial airports. The costs are significant. To secure status as a spaceport, for example Houston's Ellington Field airport would need to invest an estimated \$48 million. Nonetheless, obtaining spaceport status can boost local economies. The Mojave Air and Space Port has created some 2,500 jobs, more than half the population of Mojave, California (4,238). Two proposals, one near Denver International Airport, the other in the United Kingdom, are investigating the possibility of a spaceport for horizontal launch (rather than the traditional vertical launch atop a rocket), such as might be used by the Skylon space plane currently under development in the UK, for example.⁵⁹

These newcomers will enter a field dominated by well-established facilities like Cape Canaveral and Kennedy Space Center in the US, and Baikonur Cosmodrome in Kazakhstan. The growth in the number of such facilities in the US, while hardly running at a Starbucks pace, is still extraordinary. It reflects the expectations of commercial interest, including space tourism. Just how many spaceports an embryonic commercial and tourism space market can support remains to be seen.

In more than 50 years of human spaceflight only nine missions have ventured beyond LEO, made up entirely of Apollo flights, six of which landed on the moon. The other three were the aborted Apollo 13 flight, the Apollo 8 lunar orbit mission and Apollo 10 which test flew the Lunar Module over the planned Apollo 11 landing site. Later Shuttle missions to deploy and then service the Hubble Space Telescope had people flying to Hubble's 350 mile altitude, since the telescope must fly high above the Earth's radiant light, higher than all other manned flight except Apollo, but still well inside the range of LEO. In a sign of how times have changed since the competition between the Shuttle and Ariane, Hubble's

successor, the James Webb Space Telescope will be launched in cooperation with the European Space Agency and Arianespace atop an Ariane 5 ECA booster from the ESA spaceport in French Guiana.⁶⁰

Now, with America's human spaceflight stalled and Russia retrenching after a string of costly booster failures, only China seems to be having a good run. Orbiting the first Taikonaut in 2003 aboard a Shenzhou spacecraft in 2003, China flew its first three-member crew and conducted its first spacewalk in 2008 and carried out its first docking in orbit in 2011 with an experimental space laboratory called Tiangong-1. The first manual docking with Tiangong, a significant milestone, happened in 2012. China's Long March booster has continued to evolve, maintaining a strong performance reliability through 2012.⁶¹ The pace of China's space program is impressive, in many ways mirroring the blistering pace of Mercury and Gemini in the 1960s. But China is still playing catch-up. Its feats in space represent remarkable progress in a short time, which indicates that the nation's leaders have made space a national priority, but to date they have broken no new ground. Their achievements match those made by either the US or USSR in the 1960s and early 1970s. Just as in the US and other countries, China's space program is a source of national pride and prestige. It is therefore reasonable to expect that China will not long be satisfied with catching up. It will want to stretch its legs in space.

Despite the troubling string of Proton rocket failures going back to 2010, Russia is moving ahead with plans for new spacecraft and rockets. It plans to replace the venerable Soyuz spacecraft which has been flying in ever-updated forms since 1967 with the Piloted Transport Ship of a New Generation, or PTKNP, which could reach LEO, lunar orbit or Earth-moon Lagrange points, depending on which booster it is paired with. It would be carried atop a new series of rockets under development called Angara, which in its largest variant, Angara A7, could put 77,000 lbs in LEO, far more than any other rocket currently in service and about the same muscle as America's SLS in its initial Block 1 variant.⁶²

For its part, NASA is developing the SLS and Orion MPCV to carry astronauts atop it. The SLS was born in the wake of Project Constellation's demise, which was developing the Aries series of rockets. The SLS uses Shuttle, and even Saturn V technology and is planned in multiple versions, some for cargo, some for crew. The SLS would be only the second operational launch vehicle capable of carrying humans



Video: Space Launch System Block 1 variant liftoff animation. Credit: NASA

beyond LEO, the Saturn V being the first. The rocket in its various forms will be able to lift from 150,000 to 280,000 lbs LEO and in its largest version will be similar in lift capacity to the Saturn V, though with two million more pounds of thrust (9.2 million at lift off compared with Saturn's 7.5 million).⁶³ In a sign of just how far other space partners have come, ESA will be building the service module for Orion, which, similar to the Apollo Service Module, provides power, propulsion and avionics for the Orion capsule. This is a milestone project in many ways. Orion is the first manned spacecraft developed by the United States since the Shuttle in the late 1960s; for Europe, it marks the first time it has ever built a human-rated spacecraft. Like all such collaborations, technology transfer may be an issue though in this case the Europeans are building the service module with their own technology.

The SLS has its critics. Some have called for NASA to scrap its rocket program altogether and instead use the Falcon 9 Heavy rocket that SpaceX wants to develop--a variant of the successful Falcon 9 which has already carried the freighter version of SpaceX's Dragon capsule to the station. The SLS contractor is Boeing. SpaceX also wants to develop the Falcon 9 Heavy to service DoD payloads, but it needs the financing in order to develop the rocket.⁶⁴ It seems unlikely that this funding would come from a

cancellation of SLS. Getting NASA out of the rocket business would truly gut the agency. Based on the history of this project, though the administration might be happy to shift SLS money over to SpaceX, the opposition in Congress would likely be intense.

Plans for the orbital space plane called Dream Chaser call for launch atop an Atlas V, though the craft is “launcher-agnostic” meaning it could be mated to many different boosters. When ready to come home, Dream Chaser lands like a plane--different from the Shuttle, which landed as an unpowered glider. The vehicle has several interesting features. Its hybrid engines combine the advantages of both solid and liquid fueled rockets. Liquid fuel systems can be throttled and turned on, off and back on again. Solids, like the boosters the Shuttle strapped on to reach orbit cannot be shut off and relit--they run until their fuel is expended. The advantage of solids is they are cheaper to produce and the fuel is easier to handle. Dream Chaser’s hybrid system would use nitrous oxide (laughing gas) and hydroxyl-terminated polybutadiene (a kind of rubber). Both are non-toxic materials making the spacecraft far easier to handle. The fact that it would retain fuel for a powered landing means that, unlike the Shuttle’s glider landings, in an emergency Dream Chaser could land at a commercial airport within a thousand miles of its original planned landing site.

With Dream Chaser still in development, the world’s only space plane currently in use is the X-37B. This robotic mini-Shuttle is a US Air Force spacecraft first flown in 2010 and lifted into orbit on an Atlas V from Vandenberg Air Force Base, California. It flew unmanned on orbit for 224 days. The X-37B and the Buran shuttle, the Soviet answer to the Space Shuttle which flew just one test flight, are the only space planes to orbit the Earth unmanned. On December 11, 2012 the third X-37B mission lifted off from Vandenberg. As of this writing, the mission designated Orbital Test Vehicle-3 (OTV-3) it is still on orbit.⁶⁵ Even with all their advantages, the spaceflight Holy Grail of single-stage-to-orbit (SSTO) remains beyond the grasp of Dream Chaser and X-37B. SSTO would be a system with, as the name suggests, no staging--that is, no booster stages that fall away after their fuel is expended. The same launch configuration that lifts off the ground returns to Earth when the mission is complete.



Artist rendering of Skylon takeoff. Credit: Reaction Engines

Across the pond, British aerospace firm Reaction Engines says it is developing a truly SSTO spacecraft called Skylon. Like the public largess its American cousins rely on (detailed in the next section), Reaction Engines is building its space ambitions with \$100 million in public money, in this case from the UK Space Agency and the

European Space Agency. As envisioned, the fully-reusable Skylon will take off and land like a plane and carry twice as much cargo to the ISS as Europe's robotic freighter, the single-use Automated Transfer Vehicle, does today. Key to the concept are Skylon's two Synergetic Air-Breathing Rocket Engines (SABREs), which could be tested by 2020. The hybrid SABRE technology is the key to an SSTO spacecraft. Jet engines intake air to create combustion, but rockets are designed to operate in an environment without air, so they have to carry all their fuel with them, including oxygen. This is one reason that rockets so large and heavy. Like a jet, SABRE gets its oxygen through intakes while in the thicker lower atmosphere. But after reaching five times the speed of sound (almost 4,000 mph) and about 85,000 feet, Skylon transitions to liquid oxygen to power it into orbit.⁶⁶ The transition from air-breathing flight to rocket flight is one aspect of SSTO that creates vast technical challenges. In the current environment, greater participation by the private sector in driving technology and innovation forward may be necessary. Certainly, the 2010 NSP in the United States seems to think so.





Artist rendering of Sierra Nevada's Dream Chaser lifting off atop a ULA Atlas V.
Credit: Sierra Nevada Corp.

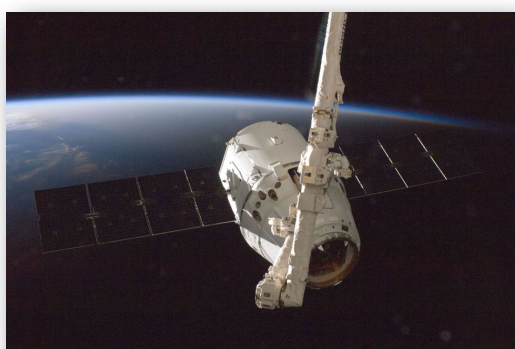
5

SPACE FOR SALE OR LEASE

NASA has a plan for rebuilding America's ability to lift people into space, but the political commitment to it has been halting and uneven. Initially, the Shuttle was to be replaced by the Aries series of rockets, paired with a new manned spacecraft called Orion, in an effort put forth by the George W. Bush Administration in 2005. Under this plan, Orion would fly by 2014 and would ferry astronauts to and from the ISS and also be capable, in different configurations, of flying back to the moon and on to Mars. A "sustained" human presence on the moon would begin by 2020 and the effort would promote international and commercial participation.⁶⁷ The whole program was called Constellation and for a time

it seemed like a reboot of Apollo. Constellation had the misfortune however of lacking John Kennedy and a Cold War. Its lifespan was short, and after President Barack Obama pulled the plug in 2010, NASA announced the Commercial Crew Program (CCP), which would use private firms to develop and operate space taxis to the ISS for astronauts. As of this writing, three contenders are all progressing, at varying levels, toward the certification needed to fly with human occupants to LEO. Sierra Nevada's winged Dream Chaser mini-shuttle will likely be paired with a United Launch Alliance (ULA) Atlas V booster; the Space Exploration Technologies (SpaceX) Dragon capsule will launch atop their own Falcon 9 rocket; and Boeing plans to launch its tediously-named CST-100 capsule atop a ULA Atlas V (Boeing and Lockheed are partners in ULA). None of these vehicles or their boosters have as yet been rated for human spaceflight. NASA has allocated roughly \$1.5 billion to these three firms for the development of CCP, a bit more than the cost of three average Shuttle flights.^{67A}

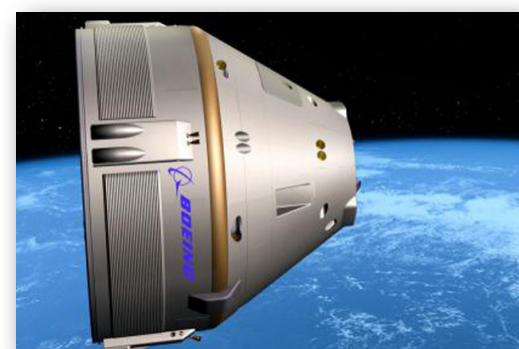
To date, SpaceX's Dragon capsule has had the loudest roar. An automated Dragon capsule made its first operational cargo flight to the ISS in 2012 atop a Falcon 9 rocket, the first-ever commercial freighter flight to the station (after which the company posted the message "Happy Berth Day, Dragon" on Twitter). The cargo flights are part of a different NASA program called Commercial Orbital Transportation Services (COTS). Besides SpaceX, Orbital Sciences is developing its Antares rocket and automated Cygnus freighter for COTS service to the ISS. Antares made a successful test flight in April 2013, and a demonstration cargo flight of Cygnus to ISS is slated for September.⁶⁸



SpaceX Dragon docked for the first time with the ISS in 2012. Credit: SpaceX



Rendering of Cygnus approaching the ISS. Credit: Orbital Sciences



Rendering of Boeing CST-100 on orbit. Credit: Boeing

Although most of the new human-rated orbital spacecraft under development, and all those currently operated by Russia and China, are a traditional capsule design (like Apollo), the dream of a space plane

didn't die with the Shuttle. Oddly, the vision of a truly reusable space plane seems as futuristic today as it did in the 1960s when the Shuttle was first conceived, making Dream Chaser the more exotic option being considered by NASA under CCP for manned missions to LEO. Even so, Dream Chaser does not chase one of the bigger dreams: a Single Stage to Orbit vehicle (SSTO), since the technical challenges are complex and expensive to pursue.

Public and commercial partnerships may be required to overcome these difficulties and move SSTO technology forward. Certainly in the United States, the 2010 NSP anticipates strong public/private collaboration in pursuit of new technologies, advanced propulsion and new spaceflight concepts. The quest for new space technologies was in fact a driver behind the Obama Administration's decision to radically alter US space policy and cancel Constellation (since it did not want to pay for both Constellation and increased R&D on new technologies). But the drive toward greater commercialization that Obama's space policy highlights brings unknown risks as well. The 1967 Outer Space Treaty and other international treaties adopted by spacefaring countries did not contemplate private space businesses working in space or space tourists. Certainly commercial actors are increasingly moving into areas previously only the purview of the space agencies of sovereign nations. The development of spacecraft by private firms and the commercial availability of global satellite navigation are both examples of this trend. One reason, says Dr. Phillip Metzger, senior research physicist at NASA's Kennedy Space Center, is cost. "It is technology that is making the difference. At one time, only national governments could afford to develop the technologies needed to launch into space. Now, our booming technological society has put the technologies into the reach of some of the (richer) private citizens."⁶⁹

The entrepreneurs driving the greater commercialization of space are schizophrenic when it comes to governments of the spacefaring powers. They are on the one hand only too happy to absorb massive public subsidies. On the other, they appear to find governments too indecisive, too timid or simply too unimaginative to confront our problems in space or to push human exploration back to the moon and on to Mars. They are therefore doing it themselves. "The way we're going, we'll never get started," Inspiration Mars founder Dennis Tito said at the May 2013 Humans 2 Mars Summit in Washington, D.C. in reference to the way national space agencies are pursuing manned Mars missions. "It's time for us to

take the first step." Inspiration Mars says it will take that step by 2018, sending a married couple to circle Mars and return, much as the Apollo 8 flight in 1968 orbited the moon in advance of any attempt to land. The mission is considering both commercial and NASA boosters. A more robust version of SpaceX's Falcon 9 rocket and NASA's monstrous Space Launch System rocket should both be available in time for a 2018 flight (assuming the development of both vehicles goes forward as currently planned). Also in the running is a combination of launches, with ULA's Atlas 5 lifting the fuel for a round-trip to Mars and a Delta 4 Heavy carrying the crew.⁷⁰

This zealous timetable puts private companies actively pursuing plans for manned Mars missions during roughly the same time frame that NASA wants to send a second Mars Curiosity-type rover to the



Mars One vision of a human colony on the Red Planet. Credit: Mars One

Red Planet.

An even more fanciful push for Mars is underway courtesy of a Dutch not-for-profit organization called Mars One, whose goal is a permanent human colony on the Red Planet by 2023. As of August 2013, more than 100,000 people have applied to Mars One to take the one-way trip, including 30,000 Americans. Only four get to make the first trip. Mars One says the first mission will cost \$6 billion. The group says they will cover that tab with commercial sponsors and media that will pay for the rights to broadcast anything and everything related to the mission, its crew and their life on the trip and then on the surface of Mars.⁷¹

The challenges of such enterprises are immense. To start with, no rocket booster built since the giant Saturn V last flew in the early 1970s has been powerful enough to break free from Earth orbit with people on board. Some are in development now, including NASA's SLS. Questions abound about how to deal with cosmic rays and solar storms once outside the Earth's protective magnetic field, the psychological pressures of such a trip (perhaps 18 months to Mars, one way), and the need to feed, supply and provide medical care for people on such a long voyage. Those issues are significant, but they only scratch the surface. Nonetheless, the private interests driving such ambitions are remarkable not least of which because they outstrip the ambitions of every sovereign nation on the planet.

While private interests in space are clearly accelerating, they are not new. In 1962, NASA launched the Telstar-1 for AT&T and by the late 1970s the commercial space sector took off.⁷² Relatively new to the scene, however, are consumers who now routinely rely on space for satellite television, navigation like GPS and Earth imaging such as Google Earth and DigitalGlobe, and using ATM cards among many other services. Also comparatively new is the space tourism business, which began when Dennis Tito bought a seat on Soyuz in 2001. In the United States, the Commercial Space Launch Amendments Act of 2004 was designed to promote a private human spaceflight industry. The act also clarified the regulatory environment for suborbital flight, empowering the Federal Aviation Administration to oversee this industry, issuing permits and determining safety standards. International safety standards do not yet exist, which is one drag on the space tourism business. Nonetheless, SpaceShipOne, the first manned private spacecraft, took to suborbital flight in 2004. A ticket into suborbital space aboard the VSS Enterprise (formerly known as SpaceShipTwo), operated by Sir Richard Branson's Virgin Galactic, will cost \$200,000 although a departure date is not yet set. While the space tourism business has generated significant press attention and made remarkable progress in a short time, not everyone is starry eyed by the prospect. Actor William Shatner, fictional captain of the USS Enterprise, namesake of Sir Richard's new spaceship, declined Branson's offer to buy a ticket into space. "I'm interested in man's march into the unknown but to vomit in space is not my idea of a good time," Shatner said. "Neither is a fiery crash with the vomit hovering over me."⁷³⁷⁴

Suborbital tourism may be an interesting venture for the super-rich, and indeed it may help to generate interest in spaceflight as a whole. But to confront the serious issues we face in space, others are leading the way. The B612 Foundation, for example, is making a concerted effort to tackle the asteroid threat. For the moment, however, the star of commercial space is the energetic Elon Musk. Musk made his fortune building, then selling, PayPal, a service that revolutionized commerce on the Internet. Now Musk is at the helm of Tesla Motors and SpaceX, pushing electric cars and spaceflight forward. Although in the press Musk is often compared to billionaire inventor Tony Stark of comic book hero *Ironman* fame, a better archetype might be Howard Hughes, not least of all because Hughes was not fictional. Hughes' imagination, technical prowess, business acumen and riches were hugely influential in the development of air travel and aerospace. Musk says he is driven by a desire to combat climate change and to colonize Mars, permanently and quickly. He says that spaceflight and the human colonization of Mars are critical to humanity's survival and, in a sentiment that seems commonplace among the commercial titans of space, he thinks time is of the essence. In this view, humanity has just a window of time in which our technical capacity to reach out into space is rising. But to assume that this technological flourishing will continue unabated is to ignore the lessons of our entire recorded history, which "would suggest that civilisations [sic] move in cycles," Musk told the Guardian in 2013. "You can track that back quite far – the Babylonians, the Sumerians, followed by the Egyptians, the Romans, China. We're obviously in a very upward cycle right now and hopefully that remains the case. But it may not. There could be some series of events that cause that technology level to decline. Given that this is the first time in 4.5bn years where it's been possible for humanity to extend life beyond Earth, it seems like we'd be wise to act while the window was open and not count on the fact it will be open a long time."

That impatience, a sense of urgency to make humanity a multi-planet civilization and to do it quickly does separate the private space bosses from their policy-making counterparts in government. But of course they need government money to make it all work. Saving humanity may work well for all the ages, but a for-profit enterprise needs to make the numbers work a bit sooner. Musk's SpaceX relies heavily on government subsidies, as did Hughes in his day. In 1947, the audacious Hughes H-4 Hercules, better known as the Spruce Goose, an eight-engine, wooden seaplane that was derided as

impossible and only made possible with government money, took to the air for its first and only flight over San Francisco Bay. Howard Hughes himself was at the controls. For his part, Musk won't be piloting a one-way trip to Mars, but he does want to make the trip. "It would be pretty cool to die on Mars – just not on impact," he said.⁷⁵

Other private entities are ploughing new ground as well. Planetary Resources, the Bellevue, Washington-based, self-described asteroid mining company launched with great fanfare in 2012 to unlock the mineral resources of the solar system for the benefit of Earthlings. The company has received funding both from NASA and DARPA that is substantial, if not yet decisive in its plans.⁷⁶ Another American company called Skycorp plans to save satellites in geosynchronous orbits from becoming more space junk once they have expended all the fuel which allows them to make the orbital corrections needed to hover above a fixed point on the ground. Skycorp's Space Life Extension System is essentially a jet pack for ailing satellites. The idea is that this system could fly to a sickly satellite, latch on and keep it in the proper orbit for as much as another decade, all for far less cost than orbiting a replacement. The Defense Advanced Research Projects Agency, which works to maintain America's military edge in technology, has similar plans.⁷⁷ The ability to recycle satellites of all kinds has broad appeal in terms of cost and limiting the creation of new space junk. The interest of the US military in extending the life of commercial spacecraft as well as its own is also understandable--80% of US military communications are carried on commercial satellites.⁷⁸

Another private actor, the B612 Foundation says that its mission to defend Earth against an asteroid impact (discussed in more detail later) can happen quicker and with more cost efficiency because it is a "private organization is that it is not bound by federal procurement regulations," as Dr. Edward T. Lu, Chairman and CEO of B612, told the U.S. Senate Committee on Commerce, Science and Transportation in March 2013. His Foundation's ability to pursue the best approach and contractor for its Sentinel mission free from the cumbersome and lengthy federal process is a significant advantage, he says. The same is true, Lu says, of B612's plan to use "high-heritage" existing hardware such as that used for NASA's proven Kepler and Spitzer spacecraft for the Foundation's Sentinel mission.

Lu also says that the arrangement between B612 and the primary contractor for Sentinel is less onerous than the typical NASA large mission, but their system works because of a small, experienced teams on both sides and because they will use proven NASA hardware designs. All these elements in tandem will allow Sentinel to fly much sooner and for less cost than if it was a public space agency mission.⁷⁹

Beyond the CCP and COTS, NASA has also been busy soliciting the private sector for innovative ways to tackle other challenges. In April 2013, NASA unveiled its Asteroid Initiative, designed to operationalize the Obama Administration's call to send astronauts to an asteroid by the early 2020s, instead of a return to the moon. On June 18 the space agency put out a public call for ideas on how best to identify, lasso and park an asteroid near the moon for study. Within a few weeks, more than 400 private firms, not-for-profit agencies and other organizations responded.⁸⁰

These are only a few examples of how the creativity of the commercial sector has been unleashed in space. The significance of the growth in commercial space can't be overstated as an element the new American space policy adopted under President Obama, even if the ultimate results of it remain unclear.

Nonetheless, a number of challenges beyond the merely technical loom as commercial interests move forward in space. The non-appropriation clause of the OST prohibits any ownership claims in space. But competition for parking slots on orbit and radio frequencies are already straining these fifty-year-old provisions. The rise of space mining will certainly challenge the non-appropriation clause and create new issues around sovereignty. In a bizarre move, even the US House of Representatives is challenging the OST, to which the United States is of course a signatory. In May 2013, US Reps. Donna Edwards (D-Md.) and Eddie Bernice Johnson (D-Texas) introduced a bill called the "Apollo Lunar Landing Legacy Act" (H.R. 2617) which would make the six Apollo lunar landing sites part of the US National Park Service, and thus sovereign US territory--an act which on the face of it directly contradicts the OST. By contrast, to date, Gen. Chilton says, sovereignty has been a pretty easy matter: "Sovereignty in space stops at the skin of your spacecraft."

But many see the “commercialization” of space both as a misnomer and a misplacement of the public trust in private hands. Indeed, commercial space has some high profile critics. Neil Armstrong and Gene Cernan, the first and last men, respectively, to walk on the moon testified passionately before the Senate Commerce, Science and Transportation Committee in 2010. The moon walkers decried President Obama’s plan to scrap Project Constellation, the Bush-era effort to return astronauts to replace the Shuttle, return to the moon and go on to Mars.⁸¹

Another critic is former NASA Administrator Dr. Michael Griffin, who, along with his predecessor Sean O’Keefe, presided over the creation of Constellation during the Bush years. Griffin told an audience at Georgia Tech in September 2012: “The near-term goal of a U.S. led, international return to the moon and the establishment of a lunar base, the logical follow-on to the now-complete ISS, has been set aside, replaced by a mission to an asteroid for which no clearly worthwhile candidate is presently available and which cannot possibly occur prior to the mid-2020s. The heavy-lift launcher being designed to re-enable lunar access has been set aside, to be replaced by the similar-appearing but less capable Space Launch System (SLS) designed to support this so-called ‘beyond LEO’ exploration. But the program is substantially underfunded, and no knowledgeable observer believes that multiple Congresses and succeeding presidents will provide the resources necessary to complete the SLS, when the only announced goal is a mission so lacking in justification that its own proponents cannot even identify the destination.”

Griffin argues that what is commonly termed commercial space is nothing of the sort, that is not “commercial” at all in the sense that a private market for human spaceflight does not exist outside government uses. To draw the distinction, Griffin notes that “while the government buys, rents, or books passage for crew or cargo on lots of airplanes, it does not provide front money for commercial airplane companies to perform product development, and, if it does not like a product that is offered, does not have to buy it.”⁸²

Gen. Chilton echoes the sentiment. “Until there’s some breakthrough in technology that cheapens the cost of the fundamental physics required to get to space I think it (Commercial Crew) will always be a government-subsidized program,” he said.⁸³

Others share the critique of the commercial path that the Obama Administration has promoted for returning the US to human spaceflight in LEO, including Julianne Sullivan, a space policy expert on Capitol Hill. Sullivan, like Griffin, says that “It’s not commercial, it’s totally subsidized. It’s far more expensive actually... if you look at just the cost of cargo per pound -- how much it costs under the SpaceX model currently to be able to get a pound of cargo to the

International Space Station is something like \$443,000,” far more than even the cost per pound with the Shuttle “which was incredibly expensive... because of how robust it had to be in order to carry humans.”⁸⁴ SpaceX claims it can send an astronaut to the ISS for less than a third the cost the US is currently being charged by Roscosmos, though the ability to do so is still years away and that cost, even if accurate, is still heavily subsidized by US taxpayers. These critiques are well-reasoned. It’s hard to see an advantage in handing public services over to private interests unless there is a clear cost savings or performance improvement, unless the investment is deemed the best way to further the nation’s industrial and technological strength. The Augustine Commission found an historical model in NASA’s CCP and COTS programs: “In the 1920s, the federal government awarded a series of guaranteed contracts for carrying airmail, stimulating the growth of the airline industry. The Committee concludes that an exploration architecture employing a similar policy of guaranteed contracts has the potential to stimulate a vigorous and competitive commercial space industry.”⁸⁵

Griffin and others are concerned that the current trend toward commercial space places NASA in danger of becoming an irrelevant pass-through agency, funneling tax dollars to private firms with



insufficient control or oversight, all done in pursuit of private profit rather than strategic national interest. They are certainly right in the assessment that commercial interests are not driven by long-term national goals. For the moment, specific long-term national space goals, well-articulated--and, in the *real* language of government, well-funded--are elusive in the US public sector. Still, private firms are driven by strategic advantage over competitors and quarterly profit. In space, they are also driven by the need to leverage public funds for the development of products that the private sector cannot support on its own, at least not for now.

Despite shortcomings and the detriment to a true national space program, the rise of “commercial space” seems inevitable, and it will further America’s industrial and technological base. The ability of NASA to leverage the creativity of the marketplace may also give America an advantage as space competition heats up, if it is properly channeled, regulated and managed by a responsible and robust public space agency. In any case, the decision by President Obama to scrap Constellation and turn LEO taxi service over to the private sector has created political muscle for space firms beyond the usual giants like Boeing and Lockheed. It has also changed the government’s investment strategy in such a way that makes the NASA-designed human-rated spacecraft under development, Orion (also known as the Multi-Purpose Crew Vehicle), too expensive to use for LEO service.

These factors, along with America’s uncomfortable reliance on Russia for taxi service to the station, would make another policy reversal of course away from Commercial Crew, and the inevitable widening of the gap during which the US has no manned spaceflight capability, politically untenable. Furthermore, the fecklessness of US space policy under President Obama has transferred the momentum of bold initiative, for the moment, to the private sector. A strong and influential government space entity will be essential if NASA, or its successor, is to be more than simply a development fund and customer for Mr. Musk and his lot.





V-2 rocket at Peenemünde, 1943.
Credit: German Federal Archive

6

SPACE SECURITY

The space age began in the middle of the twentieth century, as part of a global political and military struggle. But it's not the one Kennedy referenced in his address to Congress. It didn't begin with the Cold War at Cape Canaveral on Florida's Atlantic coast, nor even at the Baikonur Cosmodrome where the Soviet Union beat America into space with the first artificial satellite, Sputnik 1, in 1957, and bested the U.S. again with the first man in space. Instead, the space age began during a decidedly hot war in the obscure Baltic Sea port town of Peenemünde. It was at the Peenemünde Army Research Center that SS Major Wernher von Braun and his team of German rocketeers inaugurated the space age on October 3,

1942. Peenemünde was the Nazi launch site for the world's first ballistic rocket, the Vergeltungswaffe 2 (V-2). That October day, before the war had turned decisively against Germany, the V-2 launched by von Braun's team crossed the celestial Rubicon, the 62 mile mark later known as the Kármán line. But the Germans didn't design the V-2 to explore the stars. They designed it to flatten London and Paris.

Fortunately Germany hadn't the time or the resources to exploit this technology. Instead, after the war, the V-2s helped rocketry to develop on both sides of the emerging Cold War. The Americans wanted to secure advanced German technology, along with key scientists and engineers, an effort run by the Office of Strategic Services (predecessor to the Central Intelligence Agency) called Operation Paperclip. Paperclip snagged jet and rocket technology, but most important it scooped up Wernher von Braun and his V-2 team.

After Sputnik, the US Air Force moved quickly to outflank the other services and claim jurisdiction over all military space activities. Air Force Chief of Staff Gen. Thomas White told the National Press Club just weeks after Sputnik that air supremacy was essential to control of land and sea and that "there is no division, *per se*, between air and space. Air and space are an indivisible field of operations." This view, of course, put the Air Force in a position to hold sway over this vital new area. But Gen. White also put himself in opposition to Eisenhower's key objective to build an international legal framework permitting and protecting reconnaissance satellite overflights, which he considered a crucial part of US efforts to determine what was going on behind the Iron Curtain.⁸⁶ White's position that air and space were one when it comes to military operations also put him at odds with the OST several years later, which opposed the the use of force in space.

As we have seen, military considerations and Cold War rivalries loomed large in the first decades of the Space Age. Today however, the security landscape is quite different. Scott Pace, Director of the Space Policy Institute at George Washington University says that new threats are materializing to US activity in space, "threats that are different from those of the Cold War... In some cases, threats come from a known nation state while in others, it is impossible to attribute responsibility due to a lack of full 'space situational awareness' to support intelligence needs."⁸⁷ Dr. Kaminski also picked up this thread of attack

attribution, noting that in cyberspace, which connects space assets and their Earthly controllers, pinning down the source of an attack is much trickier. Indeed, a significant problem with regard to space security is the exposure of communications systems to cyber attack. In the cyber world, unlike the Cold War, “there are many actors, not just two, so identifying the source of an attack is much harder.” The inability to quickly and accurately determine the source of a cyber attack limits the options for a response. So in some ways deterrence works in cyberspace--that is, large nation states will all rely significantly on cyber infrastructure for national and space security, thus they have assets to protect and a defense posture based on some version of Mutually Assured Destruction (MAD) applies. But in a multi-polar world with smaller actors on the scene, cyber defense becomes both significantly more complicated and a critical component of space security. Furthermore, the cyber systems used to communicate with space assets (among many other things) were never designed specifically to perform the functions they are now doing. Instead they were adapted for their current use.⁸⁸

The cyber threat is detailed in a 2013 report by the Defense Science Board. In it, the Board breaks the cyber threat into six categories in three tiers, from less advanced to more. The less advanced threats include those that exploit vulnerabilities in cyber systems that already exist and are known. The threat levels advance through those who discover and exploit previously unknown vulnerabilities, up to the highest threat, state actors sophisticated enough to create new vulnerabilities through a sustained effort in combination with other organs of state power (military and intelligence assets, for example) to achieve certain political, military or economic ends. The report goes on to discuss the serious impact cyber attacks can have on US combat forces as well as the potential for disruption in critical infrastructure such as power, water and the US financial system. Significantly, the level of cyber effort required for cyber defense greatly outclasses the effort needed for cyber attack. The report estimates that 10 million lines of code were required for “unified threat management” in 2005, while malware attacks averaged just 125 lines.⁸⁹

It is in this realm that the last link to space assets must be made. The nexus of reconnaissance and communications in security policy has been important at least since Joshua reconnoitered Jericho, but in the age of cyberspace it takes on a mission critical role. Robert Dickman, Executive Director of the

American Institute of Aeronautics and Astronautics says, “To be sure, this responsibility does not rest solely with space. In the communications dimension, space’s strength really is best seen in what is called the last tactical mile – closing the link to the combatant where the big fiber network is available, and where line of sight is not suitable; that is, in most of the places where we (the United States) and our partners will fight.”

As Dr. Kaminski put it: “If I were attacking our space assets today, I would probably do my first work attacking them on the ground.” Space security and cyber security are deeply intertwined and together are also deeply enmeshed in overall national security. Indeed, both space and cyber security report up through US Strategic Command.^{89A}

Perhaps for that reason, the US Air Force views *space superiority* the same way it views *air superiority*, and the same way the Royal Navy viewed *command of the seas* from Trafalgar to World War II.⁹⁰ One difference between space, air and sea to date is that space has not yet been an active theater of war. The OST guarantees the right of passage for satellites of all kinds, including reconnaissance satellites. That right of passage may have been easier with which to agree in the 1960s when there wasn’t much a country could do about reconnaissance overflights in space. For a brief periods, new technologies can operate with relative impunity. Reconnaissance balloons in the American Civil War and later, spotter aircraft in World War I gave their users a tactical battlefield advantage until a countermeasure could be found. The same will certainly one day be said for what we now call stealth. Once these airborne assets could be successfully attacked, either from the ground or the air, the new theater of combat was opened up. Space assets similarly enjoyed a period of invulnerability from attack. But now, as China’s Fengyun ASAT test clearly demonstrated and as ongoing cyber attacks in military and commercial realms constantly show, we are already well beyond the period of the invulnerability of satellites. In fact, workable ASATs go back to the Cold War though they were never used operationally.⁹¹ So with the exception of the Fengyun ASAT test, space has been a sanctuary from kinetic weapons of war. Although maintaining space as a sanctuary from active war is a useful goal, space is, as Gen. Chilton has noted, long past a decision point of *whether* to militarize it.

Kennedy recognized the promise of space but also the real world security concerns it poses in his speech at Rice University in September 1962: “I do not say the we should or will go unprotected against the hostile misuse of space any more than we go unprotected against the hostile use of land or sea, but I do say that space can be explored and mastered without feeding the fires of war, without repeating the mistakes that man has made in extending his writ around this globe of ours.”⁹² Advancing this line of thought into policy is important for the future of humanity, but for those whom any nation charges with providing for national defense, it would be foolish to expect belligerents to blithely respect the sanctity of the Kármán Line in a hot war between actors with the ability to destroy or disrupt space systems. They are only likely do so if they mutually believe that initiating kinetic or cyber warfare in space will itself create a counterstrike placing the space systems on which they depend at risk of such degradation as to be ineffective. The means to deter the interference with space assets that would disrupt communications or situational awareness is all the more important because such disruption could be escalatory in an international crisis and could, in itself, increase the chances of open hostilities. This is why a cyber-age version of MAD may be the best way to keep the peace in space. It also speaks to the importance of developing better methods to quickly and accurately determine the source of a cyber attack, making proportionate response more likely.

During the Cold War, MAD worked in a large sense (that is to say, there was no nuclear war between the United States and Soviet Union) in part because both sides generally understood their adversary’s capabilities and intentions. In other words, deterrence doesn’t work if the adversary doesn’t know what you are capable of doing and understand your thinking clearly enough to know that you will do it. Today, however, the United States is sending mixed signals with regard to how its space security policy and civil space policies align. The confusion makes American intentions in space even murkier, both to allies and adversaries. The 2010 NSP does not embrace the idea of new binding arms treaties related to space, such as proposed by Russia and China, but it does not categorically reject them either. Furthermore, despite persistent calls in some quarters for space to be characterized as a “global commons” for humanity, or a “common heritage of all mankind,” the NSP does no such thing. Nor does it mention the creation or adoption of “norms” of responsible behavior by spacefaring nations.

Advocating international norms begs the question of who should formulate and then enforce such norms, norms to which the United States would be bound along with everyone else, and so successive NSPs have studiously avoided this language. Despite this, the National Security Space Strategy, released within months of the 2010 NSP and signed by the Secretary of Defense and Director of National Intelligence has a different view. The latter document says, in part, that the Pentagon “will support establishing international norms and transparency and confidence-building measures in space, primarily to promote spaceflight safety but also to dissuade and impose international costs on aggressive behavior.” But as Dr. Pace of the Space Policy Institute notes, this phrase “goes beyond the terms of the National Space Policy.” He says that the Pentagon compounds the confusion by using “the legally problematic term ‘global commons’ with respect to space in its most recent Quadrennial Defense Review, dated February 2010. This term applies to the high seas and the air above them, but is not yet accepted internationally or even officially by the United States.”⁹³

To have the Defense Department advocating for international norms at the same time the United States is opposing a new treaty for space conduct is problematic at best. Given all that America in particular has at stake in space, sending such mixed messages is certainly unhelpful. An update to the National Security Space Strategy, issued as Department of Defense Directive 3100.10 in October 2012, makes no mention of “global commons” or “common heritage.” It does seek to expand the DoD’s level of cooperation in space with international partners, including cooperation in “developing, designing, acquiring and operating” space systems, extending the “battlefield advantages” of space systems to allies, and working with allies to protect against issues arising from dual-use technologies.⁹⁴

Although dual-use technologies and related technology transfer concerns will continue, the growth in the commercial use of space will also serve to make space technology more affordable and accessible. This in turn has the benefit of enabling more spacefaring nations and more organizations that will then also rely on space assets, “thereby creating a wider pool of stakeholders with a vested interest in the maintenance of space security,” says the Space Security Index 2013.⁹⁵ There is a hope that more customers increasing the frequency of launches worldwide will also help to control launch costs. Cost control is one reason that the Defense Authorization Act for 2013 enables DoD to share launch vehicles

with commercial users. Lower launch costs enable users to orbit more capable, and more robust, systems for the same money.⁹⁶ At the same time, as noted in Chapter 3, the technological, security and political dynamics are changing. Paul Kaminski says that, “Up until just a few years ago our national space policy played an extremely critical role in US national security and also had a very significant impact in our international security and international security strategy.” But, again, these products and services are becoming commoditized.

Dr. Kaminski notes that while Russia remains a “near-peer” competitor with the United States in space, it is China with the seriousness and the “economic wherewithal” to be a “true peer competitor” in space. Recognizing the vulnerabilities of relying too heavily on space in an environment that includes a peer competitor that could disrupt or destroy space assets, the US is beginning to take steps to either compliment or supplement these.⁹⁷ The rise of a potential peer competitor to the US in space has broad implications beyond national security as well. The opportunities this creates may be reflected in the 2012 DoD Directive calling for more international cooperation in defense related space capabilities. As America’s relative advantage in space capabilities declines, its appetite for cooperation on the civil side of space may also rise. This increase in cooperation, in turn, may have a positive effect on overall security provided that legitimate technology transfer concerns had be assuaged.

The desire to keep the peace in space was a very early international objective in the space age. To date this desire has been fulfilled, at least insofar as space has not been home to open human conflict. But space is not a panacea, disconnected from the all too real Earthly ambitions and security concerns of nation states. Indeed, it has become deeply connected with human efforts to keep the peace on the ground. As we have seen, space assets have been used to verify arms treaties, determine the capabilities of adversaries, locate troop movements, communicate and help forces find their way on land, sea and air. Moreover, deterrence depends on the ability to understand one’s adversary. Space enables that understanding in a unique way.





Near the Yucatan Peninsula, between 66.03 and 66.04 million years ago.

Credit: Universe Today

7

HOUSTON, WE HAVE PROBLEMS

Having outlined examples of major international cooperation in space, the politics that drove certain decisions and the security environment related to space, we now turn to specific problems. The chaos in America's manned space program and the string of troubling failures in Russia's rocket boosters relate to internal domestic issues within each country that still affect the international community. The spreading hazard of orbital debris is a disproportionate threat, challenging nations more which rely more on space assets, though still a global problem. The need to create more robust situational awareness in the near-

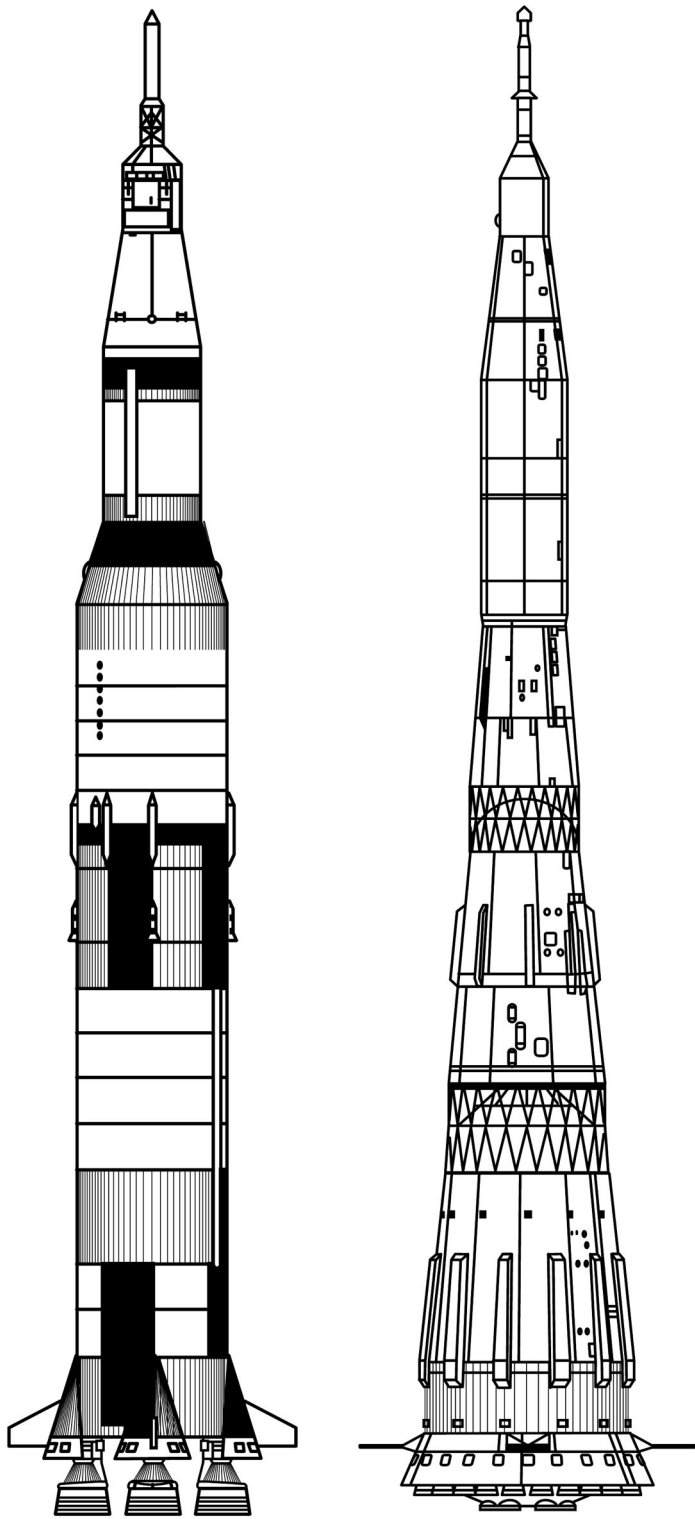
Earth area and build a planetary defense against near-Earth objects focuses on a global and potentially even existential threat.

Confronting these last two issues in particular will depend on strong international leadership, or it will suffer from a lack of it. As the number of spacefaring nations and organizations grows, the need for leadership to marshal resources on an trans-national, even planetary scale becomes all the more pressing. Complicating the problem, national rivalries in space are re-emerging as both of the historical leading space powers stumble.

America in search of a mission

Almost from the very moment Commander Neil Armstrong pressed humanity's first footprints on another world, America's manned efforts in space went out of focus. NASA had planned ten Apollo landings on the moon, then a follow on space station, Space Transportation System (the Space Shuttle fleet), a Grand Tour of the outer solar system using robotic spacecraft and a manned mission to Mars, all by the 1980s. By the time he became president in January 1969, Richard Nixon inherited a space program nearly ready to bear fruit. But Nixon had little of Kennedy's public zest for the space race. His public comments with regard to space were far more cautious and qualified, even as he announced a bold program like the Shuttle. He was keen to internationalize US space efforts in some way which meant they would necessarily take more time to unfold than if they were purely American projects. Nixon had, for example, expressed frustration that the Apollo flights had not carried foreign astronauts in addition to Americans (something he had no opportunity to influence during Apollo's formative years).⁹⁸

Project Apollo had grown from Kennedy's stated goal of landing *a* man on the moon to a plan to land 20, two moon-walkers in 10 flights, culminating with Apollo 20. In the end, the United States made just six moon landings from 1969 to 1972. The hardware was already in place for all 10 flights, but a failure in the Apollo 13 Service Module *en route* to the moon aborted that landing and Apollo 18, 19 and 20 were canceled due to budget cuts. The reasons are many, but certainly one was that Nixon could read polls as well as anyone. Even during the heady run-up to Apollo 11, polls showed the American public was deeply divided over whether Apollo was a good use of public money.⁹⁹ During much of Project Apollo, America



The US Saturn V moon rocket, left, and Soviet N-1 moon rocket, right. Credit: fr.academic.ru

was fighting two wars, one against poverty, the other against North Vietnam. A majority of Americans felt that the money going to the space program could better be spent at home, a sentiment that Sister Jucunda's plaintive letter to NASA symbolizes.

Nonetheless, a decade earlier, Kennedy acted decisively on his concerns about the US lagging behind in space, and the implications that reality would have for America's technological edge as well as what that perception would mean for America's soft power in the global conflict with Soviet Russia. Remarkably, now top US officials grappled with the impression of diminishing American power and prestige even in the immediate afterglow of the triumphant Apollo 11 landing. Nixon had already decided to cancel the final three Apollo flights, but he was now considering cutting the moon program loose after Apollo 15, meaning there would be just four landings. After all, America had beaten the Russians to the moon and technical problems looked as though they would keep the moon free of any red banners. The most significant technical problems were that

Soviet moon rockets, the giant N-1s, kept exploding. Of the four N-1 test launches, all the vehicles failed, some creating the largest non-nuclear explosions in human history. Russia's manned moon program was sagging. But Caspar Weinberger, then Director of the Office of Management and Budget, wrote in an August 12, 1971 memorandum to President Nixon that he opposed canceling Apollo 16 and 17. "It would be confirming in some respects, a belief that I fear is gaining credence at home and abroad: That our best years are behind us, that we are turning inward, reducing our defense commitments, and voluntarily

starting to give up our super-power status.”¹⁰⁰ The president agreed, so the Apollo moon missions flew into 1972.

Since the successful Apollo 11 landing had made the moon race politically moot and the spectacular (albeit secret) failures of their own rockets put the moon out of reach for Cosmonauts, the Soviet Union had shifted its attention to the development of orbiting laboratories, “space stations,” just as von Braun and Johnson had feared ten years earlier. Thus a “space station gap” was developing that would feed a long-term policy debate about the need for the United States to build a station of its own.

Like Kennedy and Eisenhower before him, Nixon would not sign off on NASA’s long-term vision but the space agency kept on pressing for a space station, knowing that this would be an important milestone on the way to Mars. After Apollo, US space policy made a marked shift from urgent and strong executive support for ambitious and clearly defined long-term goals to the more complex incremental approach that has characterized it ever since, an approach that is much more in line with other federal agencies. A good example of this can be found in President Nixon’s 1969 request that Vice President Spiro Agnew report to him on recommendations for America’s future space efforts. When President Kennedy had given Lyndon Johnson the same task in 1961, the vice president responded in just eight days. Agnew delivered his report to Nixon in 214 days. It took a further six months for Nixon to respond. Space, it seemed, was sliding down the presidential pecking order. Nonetheless, Agnew’s Space Task Group wasn’t terribly modest in its goals. It called for a manned mission to Mars by the end of the 20th Century, though they thought NASA could be ready to make the trip as early as 1986. It also called for a space station and a lunar base.¹⁰¹

Since a major space station would be far too large to lift into orbit in one piece, such a project would need to be orbited in modules aboard versions of the huge Saturn V moon rocket, then assembled on orbit--a staggering undertaking. To support the station and provide “airline type operations” to ferry people, supplies and components to and from orbit, a new vehicle was called for. NASA called it the Space Transportation System (STS), but the reusable orbiters which were the major component of STS would become universally known as the Space Shuttles. The Shuttle was revolutionary in countless

ways. It was the first manned spacecraft to use solid-fueled boosters (which cannot be throttled), the first with wings, the first with a heat shield and engines that could be reused, the first to land like a plane, transitioning from orbital speeds to hypersonic unpowered flight during re-entry, the first reusable vehicle overall, the first to fly manned for the very first test flight and the first manned spacecraft with no crew emergency escape system.

The Columbia Accident Investigation Board (CAIB) noted that the Shuttle is a marvel of engineering, but found that the budget pressures and high expectations of the time led to a space plane where “the increased complexity of a Shuttle designed to be all things to all people created inherently greater risks than if more realistic technical goals had been set at the start. Designing a reusable spacecraft that is also cost-effective is a daunting engineering challenge; doing so on a tightly constrained budget is even more difficult.”¹⁰²

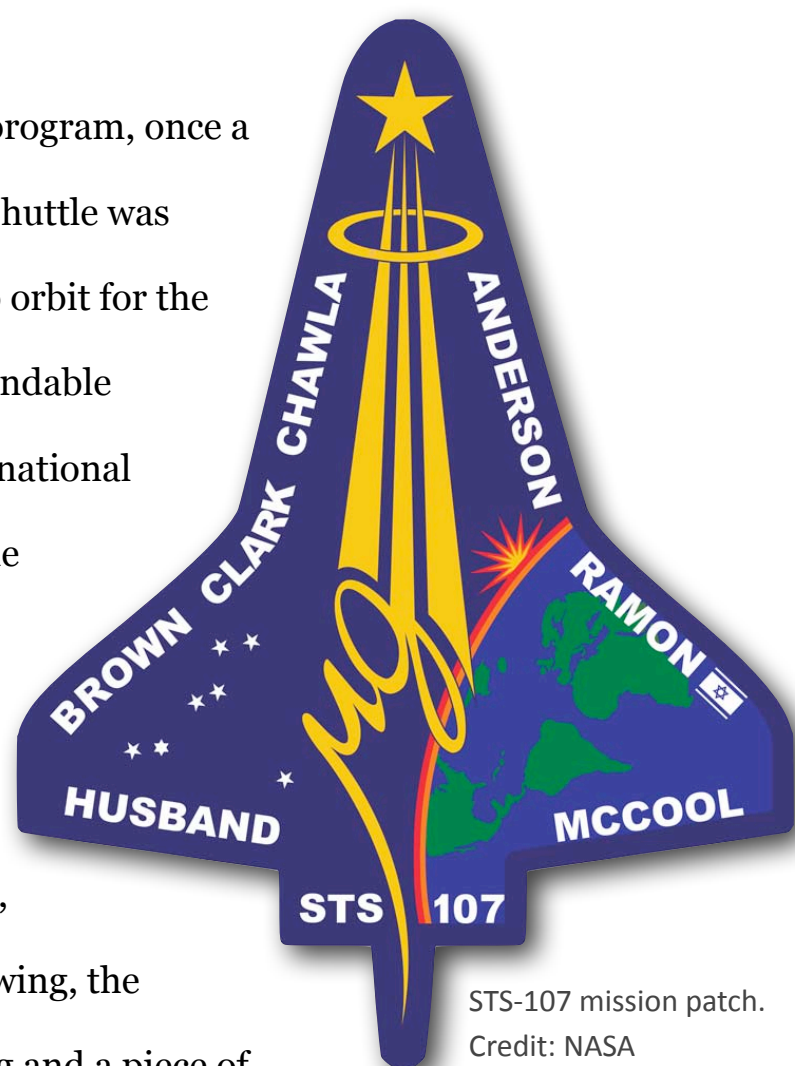
At the same time NASA’s post-Apollo wrangling with Nixon was going on, widening the Shuttle’s uses while winnowing its budget, Wernher von Braun’s vision of a huge orbiting pinwheel that would rotate in space, using its centrifugal force to create artificial gravity around the outside of the wheel had captured the public imagination in, among other things, Stanley Kubrick’s seminal 1968 film *2001: A Space Odyssey*. Unfortunately for NASA and von Braun, it evidently did not capture Nixon’s. He would not approve the space station, but he did approve development of the Shuttle--ironic since the primary mission for the Shuttle would have been supporting the station.¹⁰³ Ultimately, Nixon did approve a less ambitious orbiting laboratory called Skylab, created partly from from the already-built upper stage of what would have been the Apollo 18 launch vehicle, though the Shuttle was not necessary to build or support SkyLab.

From this point forward, the White House would write NASA no more blank checks. America’s space program would scratch and fight with every other federal agency for funding and support. Nixon budget officials saw little value in manned spaceflight at all, given the enormous costs, so with the space station off the table as a justification for the Shuttle, NASA began looking for an economic reason to build the Shuttle fleet. When the space agency added up the annual number of US commercial, scientific and

military payloads, it reasoned that 50 Shuttle launches every year could lift everything America needed to put on orbit. At that extraordinary launch rate (which the Shuttle never came close to achieving) the economics of the Shuttle might even work. Despite those rosy projections, Nixon approved the Shuttle in 1972, in part to create jobs in key states during an election year and in part due to a warning from NASA Administrator James Fletcher, who, in a memorandum to the president, said: “For the U.S. not to be in space, while others do have men in space, is unthinkable, and a position which America cannot accept.”¹⁰⁴ Those words, used to justify the birth of the Shuttle, could just as easily have been written in 2011 at its demise. Again, the political calculus here was dominant. With Weinberger and Fletcher warning Nixon about the blow to American prestige if the nation were left without a worthy successor to Apollo, the Cold War still played a central role in decisions about America’s future in space.

In the lead up to Apollo, NASA Administrator Webb felt he had strong enough presidential support to offer truly realistic budgets for the moon program, which made cost overruns less likely and a schedule easier to keep. This advantage evaporated for his successors. The budget pressures created by a more incremental and constrained approach would lead to costly, and ultimately tragic compromises in the philosophy but also the design of the Space Shuttle.

Since President Nixon had scrapped the Saturn rocket program, once a space station project was being designed years later, the Shuttle was charged with the task of lifting space station modules into orbit for the US, while Russia would carry other modules aloft on expendable rockets. In 2003, with construction to finish out the International Space Station picking up steam, the busiest year yet for the Shuttle fleet lay ahead.¹⁰⁵ Before station construction continued, however, a pure science mission was scheduled for the Shuttle Columbia, mission STS-107. Columbia flew 6 1/2 million miles, 255 orbits of the Earth, over 16 days, all with a bowling ball-sized hole in her left wing, the product of a collision between the leading edge of the wing and a piece of



STS-107 mission patch.
Credit: NASA

thermal insulating foam that broke free from Columbia's massive external fuel tank just 82 seconds into flight on January 16. Foam strikes had occurred on previous Shuttle flights and NASA managers, made aware of the strike by high resolution photography of the launch available the following day, determined there was no cause for concern. Mission Control informed Columbia's crew about the strike, and said it would not affect their mission. But that suitcase-sized bit of foam insulation would not only doom Columbia, it would be the catalyst for retiring the entire Shuttle fleet.

On February 1, as she descended into the Earth's atmosphere at 15,000 miles per hour, the leading edge of Columbia's wings heated up to nearly 3,000 degrees Fahrenheit, about a third that of the surface of the Sun. Like all re-entering objects, the Shuttle's incredible speed created an intense pressure wave at its leading surfaces as it began to encounter friction from the steadily thickening atmosphere. This pressure wave transformed the air in front of the Shuttle into a blistering hot incandescent plasma, which flooded into the structure of her wing through the hole created by the foam strike. Columbia disintegrated over the southwestern United States, killing all seven of her crew. Parts of the orbiter were found in three states.

The Columbia Accident Investigation Board (CAIB) issued its report in late 2003. Like the investigation report after the disintegration of the Space Shuttle Challenger 25 years earlier, it was withering. The CAIB concluded that while compromises made in design itself did not make the vehicle fundamentally unsafe for human spaceflight, the Shuttle had, nonetheless, had its day.

The CAIB found that "one of the major problems with the way the Space Shuttle Program was carried out was an a priori fixed ceiling on development costs. That approach should not be repeated."

In 1986, when Challenger STS-51-L exploded 73 seconds into flight, the Shuttle program was still new. America had bet its entire spaceflight future on the Shuttle, and spent billions to develop it and build out the fleet. It was politically untenable to simply scrap the Shuttle. But by 2003, the CAIB evidently felt it could label the Shuttle a "complex and risky system."¹⁰⁶ Moreover, the ISS, while far from complete, was well underway. Servicing a space station had been a primary mission of the Shuttle from the very

beginning, and later on, building the station was a major Shuttle mission. In 2003, ISS completion was at least in sight.

The Shuttle's costs were a focus of deep criticism of the program. Indeed the half billion dollar cost of a Shuttle flight was far above the cost of other flights to the station. Part of the emotional depth of the cost critiques of the Shuttle was that many people believed that cost effectiveness was a primary *raison d'être* for the Shuttle. After all, it was a cheaper, reusable, more reliable space transportation of the future, right? Not exactly. As the CAIB detailed, design compromises and budget constraints meant the Shuttle was not a fully reusable system. Further, the presumed cost savings of a partly reusable system like the Shuttle had only been highlighted after Nixon nixed the space station, so the Shuttle's advocates cast about for other ways to promote the program.

The CAIB noted that after Apollo the US manned space program had flown for thirty years “without a compelling national mandate.”¹⁰⁷ The Board was equally unambiguous in their judgement of the link between political leadership and suppositional fixed budgeting for developing the next generation of manned spacecraft in furtherance of national objectives. “It is the view of the Board that the previous attempts to develop a replacement vehicle for the aging Shuttle represent a failure of national leadership.”

The Board (writing in 2003) further noted “that past and future investments in space launch technologies should certainly provide by 2010 or thereabouts the basis for developing a system, significantly improved over one designed 40 years earlier, for carrying humans to orbit and enabling their work in space.”¹⁰⁸ Ironically, the launch vehicle that NASA is developing for the future, the Space Launch System, or SLS, uses upgraded versions of the Saturn V F-1 engines that were first designed by von Braun's team in the 1960s.

The CCP and COTS programs were designed to keep the ISS supplied with astronauts and cargo, respectively. CCP is especially important since the US has lacked the ability to fly people in space since 2011 when Atlantis STS-135 rolled to a stop at Kennedy Space Center and the Shuttle era ended. For all the romance retrospectively attached to the Shuttle era, Gen. Chilton, who piloted STS-49 and STS-59

and commanded Atlantis STS-76, says that with the nation only willing to spend so much money on space, “to move forward beyond Low Earth Orbit, the Shuttle program had to come to an end.”¹⁰⁹



Video: Final Shuttle landing, Atlantis STS-135. Credit: NASA

Russia has enjoyed uninterrupted human access to space since Yuri Gagarin. But for the US, the current gap in human spaceflight capability is its second. Six years passed between Apollo-Soyuz in 1975 and the Shuttle Columbia’s first flight in 1981. Yet when Apollo ended, the Shuttle was by then a well-defined program. The Apollo-Shuttle gap was supposed to be smaller, but the Shuttle was a revolutionary and complex vehicle and it ran years behind schedule. Even so, the Shuttle program in its formative stages had clearer outlines than SLS/Orion, which continue to shift, and even the *planned* US manned spaceflight gap this time around is nearly a decade. In the meantime, concerns are rife among ISS partners over the sole reliance on Russia for access to the station. Technically, the United States is using Russia to fulfill a number of its promises to ISS partners, which call for the US to provide access to the station (via the Shuttle or successor vehicle), and to provide a “crew rescue vehicle with capabilities to support the rescue and return of a minimum of four crew.”¹¹⁰ NASA has an agreement to pay

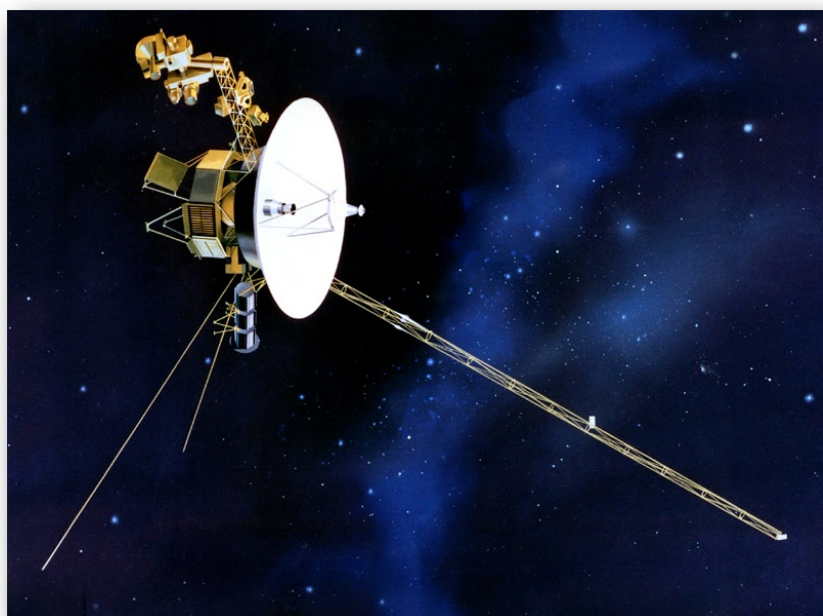
Roscosmos, the Russian Federal Space Agency, \$753 million to transport astronauts on Russian Soyuz vehicles to the station through 2016, about \$70 million per seat.¹¹¹ Similarly, the US government abandoned plans to develop the Orbital Space Plane (OSP), a sort of mini-Shuttle that would have been used as an emergency escape vehicle for the station, and for nominal crew and cargo transport to and from the station.¹¹² Work on the OSP was transferred to the Crew Exploration Vehicle (later recast as the Orion Multi-Purpose Crew Vehicle), which has yet to fly, although commercially the OSP does have new life in the form of Sierra Nevada's Dream Chaser. As a result, accommodations were made for an additional airlock at the station, so that two Soyuz rescue capsules are docked at all times, which could meet crew evacuation requirements in the event of an emergency.

In the past few years, America's manned spaceflight program has gone from having no "compelling" national mandate to have no mandate at all to speak of. For all its virtues as a heavy-lift booster, the SLS is just a rocket. It is part of no as yet coherent program of exploration. As we have examined earlier, the Apollo period was an anomaly in many ways. But even by today's incremental standards, the Obama Administration's current "flexible path" to Mars is a roadmap to nowhere in particular--literally. The "flexible path" has astronauts visiting an as yet unidentified asteroid of some kind, somewhere in the neighborhood, at some point in the mid 2020s, and then a trip to *somewhere* in the vicinity of Mars *sometime* in the 2030s. Inspiring it is not. The administration later floated the ideas of capturing an asteroid and parking it near the moon and/or building a small space station on the far side of the moon. One has to squint pretty hard to find a coherent narrative in America's manned space program.

Constellation may or may not have been the right approach to get people to Mars, which all nations seem to agree is the ultimate goal. But it at least was a coherent approach--a full program, with timetables, though woefully underfunded. The program would have centered on an American-led, international return to the moon, with the establishment of a base there which could be used as a way-station to Mars. As the Augustine Commission noted, Constellation's timetables were unrealistic because the program just didn't have the money. With no willingness to spend sufficient funds on Constellation, President Obama interpreted the Augustine Commission findings to mean that Constellation was "unexecutable."¹¹³ President Obama described the change in space policy as a "'bold new approach to

human space flight that embraces commercial industry, forges international partnerships, and invests in the building blocks of a more capable approach to space exploration."¹¹⁴

In fact, the president appears to have no interest in the moon and no interest in continuing development of a heavy-lift rocket or the Orion capsule, either. The administration's central idea was that space technology was stale, and that the money being put into these programs should instead be spent on developing radically new technologies. The Congress did not see it that way and so the administration grudgingly accepted the idea of building the SLS and Orion.¹¹⁵ Charles Bolden, the NASA



Voyager 1. Credit: NASA JPL

Administrator, vigorously defended the current US policy at the Humans 2 Mars Summit in 2013, saying that the US approach is in fact the only way to the Red Planet. He said for example, that only the incremental approach to booster development, the SLS, will work. "What happens if we are forced to go right to a 130-metric-ton vehicle (as opposed to the planned 70-metric-ton to LEO initial Block 1 version

of the rocket) is that we are perilously along the way to what happened with Constellation, where we have a very robust launch vehicle and no money, no assets, to develop the other systems that allow us to explore," he said. This is a reflection of the Augustine Commission report, which had said that America was spending enough money to either build a manned exploration infrastructure or to operate one, but not both. Bolden went on to say that while the Commercial Crew program was essential to getting to Mars, the moon was not. A stop on the lunar surface would drain too many resources needed for Mars. "If we starting straying from our path and going to an alternative plan, where we decide we're going to go back to the Moon and spend a little time developing the technologies and the systems we need, we're doomed. We will not get to Mars in the 2030s, if ever, to be quite honest."¹¹⁶ Essentially, Bolden is acknowledging the reality that his agency just doesn't have the money for both moon and Mars.

It's not all doom and gloom of course. America's robotic explorers are roving all over Mars. In fact, America's fleet of robotic spacecraft throughout the solar system has no peer. Mars Curiosity's entry,

descent and landing heroics, Voyager's trip to become humanity's first interstellar spacecraft and Kepler's planet-hunting prowess are just three recent examples. So when it comes to unmanned, robotic exploration, the US is riding high and has been for some time. When astronauts enter the equation, NASA's fortunes become far murkier. By this time, with ten years of zig-zagging after the Columbia disaster and ever more scarce funding, Bolden may be right that changing gears yet again would mean more wasted time and money. As Brendan Curry, vice president of Washington operations for the Space Foundation put it: "The problem is you can't have these wild swings every administration, every Congress. You can't sustain the program, you can't fund it."¹¹⁷

The frustration in Congress is nonetheless palpable. "It seems like almost all other nations want to go to the moon; whereas, this administration wants to go anywhere but the moon," said J.T. Jezierski, staff to the House Science, Space and Technology Committee.¹¹⁸ In July 2013 a House subcommittee, along party lines, approved a two-year NASA authorization bill that would ban the president's asteroid capture mission and require more manned exploration in preparation for a voyage to Mars, among other changes. These are important questions and Congress seems to be jumping into the breach at least in part because of what they see as timidity on the part of the administration. In any case, the open schism in Washington between the president and the Congress over space policy can only serve to create further questions among spacefaring nations about America's reliability as a partner in space operations which are by definition long-term projects that require some measure of stable political support. The open hostility between the executive and legislative branches in Washington over space policy bodes poorly for American leadership.

Greater commercialization, growing spacefaring capabilities around the world and a rising number of spacefaring nations, combined with a meandering, uninspired US space policy, partisan gridlock and severe budget constraints all conspire to diminish America's leverage as a global leader and reliable partner in space. This would therefore seem an ideal time to bolster alliances with traditional space partners. Instead, the Obama Administration has done just the opposite.

When President Obama canceled Constellation in 2010, *The New York Times* noted that plans for future exploration made it obvious “that any future exploration program will be an international collaboration, not an American one, more like the International Space Station than Apollo.”¹¹⁹ And yet the administration scrapped Constellation with no prior consultation with US allies. The US made it clear that the moon held little interest for its space program--been there, done that. Again, US allies and spaceflight partners were caught by surprise. They have all been planning in various ways for a lunar return as a stepping stone toward Mars.

Then in 2012, ESA-NASA cooperation on Europe’s ExoMars mission scheduled for 2016 fell apart when, after seven years of planning, President Obama’s FY 2013 budget left ExoMars on the cutting room floor. Europe quickly found a willing ExoMars partner in Moscow. Even so, Europe is realistic about the many reasons for the US decision on ExoMars, noting in its Secure World Foundation conference report in September 2012, that the “withdrawal of the United States from the joint ExoMars mission can be attributed at least partly to a lack of proven track record in planetary landing for Europe.” Moreover, the European powers realize that the “complex nature of Europe’s space governance” is a problem and that “the United States, for example, considers the multiplication of institutional actors within European space policy to be a real challenge.”¹²⁰ American space policy, historically the domain of the executive branch, is crowded with other institutional actors today as well.

The problems don’t end there. The weather satellites so critical to storm prediction (discussed in Chapter 3) are aging and now seem certain to die before replacements can be orbited, even though the geriatric nature of these vital assets has been well known for years. These satellites fly polar orbits, imaging longitudinal swaths of the Earth below, one swipe at a time. NASA and the National Oceanic and Atmospheric Administration (NOAA) plan to orbit the Joint Polar Satellite System (JPSS) as replacements, but the current launch planned in 2017 is years behind schedule and it now seems virtually certain that a gap in accurate forecasting will exist between the failure of the current system and the new JPSS.^{120A} The inability of the US government to replace such critical systems in a timely way not only endangers life and property, it, like the human spaceflight gap, bespeaks a lack of proper management, clear priorities, realistic funding and, most of all, political leadership.

American political leadership in space was also *not* on display at the 2013 National Space Symposium in Colorado Springs, an event sponsored by the not-for-profit Space Foundation. While representatives of China, France and Germany joined an estimated 9,000 participants, NASA--space agency of the host country--was not present. The space agency's absence was a result of travel restrictions in the wake of the US federal budget debacle commonly known as the sequester. "We talk about being a leader in space exploration," said Elliot H. Pulham, the chief executive officer of the Space Foundation. "But it's hard to be a leader if you don't show up." ^{120B}

The growing importance of space has also prompted some to question the structure of the space program and space operations on both the military and civilian side. This topic is worthy of serious study well beyond the scope of this paper, but here we will outline a few of the proposals and offer a brief analysis. On the military side, the US Air Force has held bureaucratic dominion over space from the very beginning, while NASA was created to be the primary agency for space exploration, space science, space and aeronautical research.

There have been proposals to, for example, create Space Corps that would be technically under the Air Force command structure, but autonomous, akin to the Marine Corps' relationship with the Navy; other plans would restructure along the lines of the Army Air Corps, a predecessor the the US Air force that was quasi-autonomous within the Army.

In a 2000 paper called "The Guardians of Space," Air Force Lt. Col. Cynthia McKinley proposed the creation of a United States Space Guard, along the lines of the US Coast Guard, arguing that the USAF should "relinquish its non-core, non-war-fighting responsibilities for providing space services," and that these services should be combined into a single operational organization--the US Space Guard. She argued that within the Air Force, cultural, financial and organizational tensions exist which degrade the ability of the service to manage space efforts well over the long term. In this theory, culturally the Air Force's core "fly and fight" mentality is incompatible with its non-war-fighting space operations. The combat operations of the Air Force create different priorities and mentalities than space operations which are necessarily support functions, i.e. orbiting, flying and servicing spacecraft, then getting the

communications or other data they collect to the right people who often are not within the USAF or even the US government. Financially, the tension revolves around war-fighting vs non-war-fighting spending. For example, the Air Force can decide how many tankers it actually needs or at least how many it can manage with, but in space it has effectively created national and global utilities. GPS was originally designed for military use but is now used commercially and ubiquitously all over the world. Space situational awareness through the US Space Surveillance Network is available to all spacefaring nations¹²¹. Many nations check in with the SSN when planning a space launch to make sure they have a clear path to orbit.¹²² The friction created by paying for these space related support functions, especially those “global utilities” remains an unresolved problem within USAF space operations. Her third tension, organizational, relates to this same issue. For example, she asks: “Is it an Air Force responsibility to provide orbital collision avoidance data or analysis of satellite malfunctions to commercial interests?”

Her answer is to reorganize all the USAF space functions into a US Space Guard, and as support for this, she demonstrates how many of the services provided by the Coast Guard in US territorial waters--waterway management, navigation, seaport security, boating safety, pollution control and rescue, for example--have allegories in near-Earth space that are being provided by agencies less well suited to manage them for the reasons outlined above.¹²³

When Lt. Col. McKinley wrote about the Space Guard, in 2000, the space environment was different--less congested, less crowded. Commercial space had not yet picked up steam. The US budget had not endured the hammer blows of huge tax cuts, the wars in Afghanistan and Iraq, the Great Recession, rising entitlements or the (grammatically incorrect but commonly used) “sequester.” Some of these developments at least may give even more reason to study this idea. For example, an ever more congested and crowded space environment may ultimately demand a branch of service dedicated solely to its management as a core function. On balance, however, while worthy of further study some of these arguments ring a bit hollow. Space functions, for example, are not the only support functions within the Air Force. Every military organization has war-fighting functions and support functions which co-exist. The Air Mobility Command based in the St. Louis, Mo area provides logistical support for the US

military worldwide, yet it exists within the structure of the Air Force. Indeed, one could argue that any organization of any kind has mission-fulfillment functions and the support functions that enable them. The distinction that she draws about the fundamental difference of space functions is therefore interesting but unconvincing.

Furthermore, in the past decade, space functions have become woven into the Air Force and its budget. The idea that safe and secure space operations are necessary, even critical, every day for both military and civilian uses is a central tenet on which this paper is based. Asking the Air Force to relinquish their mastery over this budgetary and bureaucratic domain would create an epic tussle, one which would become an unnecessary distraction unless the Air Force leadership was convinced that separating space functions would best serve *both* the nation and the Air Force.

An even more grandiose proposal, made by no less than Edwin “Buzz” Aldrin along with the Aerospace Technology Working Group (ATWG), is the combination of some NASA functions along with those of other departments to create a cabinet-level US Department of Space. Under this plan, the Space Department would be responsible for dealing with space exploration, orbital debris and planetary defense (three of the most pressing space issues dealt with in this paper), commercial spaceflight, global space infrastructure development, the creation of space based solar power, space fuel depots and other issues. NASA would lose most space exploration and space operations to the new Space Department, but gain money for space technology, aeronautics and the development of leading-edge experimental projects.¹²⁴

This proposal, while also interesting, is significantly less well-baked than the Space Guard scheme. The ATWG proposal is substantially a critique of President George W. Bush’s Vision for Space Exploration (which effectively launched the ill-fated Project Constellation). ATWG, while an interesting intellectual exercise, also fails to lay out a compelling case for why the current structure is unworkable. Beyond that, the proposal more than doubles US spending on civil space (outside DoD spending) and includes massive new projects like the space based solar power and space fuel depot proposals. These projects may well have scientific, technical and even national security benefits, but the current budget

environment makes their enactment exceedingly unlikely. Indeed any possible advantages of reorganization into a Space Department will be politically overshadowed by the extraordinary costs attached to it from the outset--this hardly seems a recipe for success in Washington. Moreover, the task of reorganizing numerous US functions from many departments into a US Department of Homeland Security worked (if indeed it has “worked” functionally, a subject not taken up here) because it was driven by the trauma of 9/11 and the feeling that the government needed to do a better job of communicating and coordinating in order to protect the public. A case could be made that the asteroid threat (discussed later) presents similar issues. In order for a real discussion on federal reorganization at this level to take place, planetary defense would have to be a burning public concern, coupled with a general agreement that NASA and other agencies, in their very organization, are not up to the job. The asteroid-related events of 2013 have certainly heightened public awareness of the issue, but not to a critical level.

Russia’s launch program needs a boost

On July 2, 2013 a Russian Proton-M booster lifted off from the Baikonur Cosmodrome in Kazakhstan with \$200 million worth of satellites for GLONASS. The GLONASS satellites were to reach an altitude of 12,500 miles, but they came up a little short. Just after liftoff, the rocket began to zig-zag, made a u-turn and broke up just feet above the ground and slammed into the Earth just a mile away from its launch point in a huge fireball. The incident was especially embarrassing for Roscosmos, since dramatic video of the launch failure circled the globe on YouTube and Twitter within moments.

More important, however, it was just the latest in a string of troubling and costly failures by the space agency which at the moment provides the only taxi service to the ISS. Russia’s reputation as a reliable launch provider has been struck by a series of hammer blows since 2010. This was in fact the third Proton failure since 2010, along with a Soyuz-2 rocket failure in 2011 that led to the loss of an unmanned Progress ISS resupply freighter, and the total loss of the Phobos-Grunt mission in 2011 due to another Proton failure.¹²⁵ The reliability numbers are stark for Roscosmos, especially given Russia’s position as the world’s space launch leader in 2012. The Proton M launcher, a mainstay of the Russian launch fleet,

has a 90 percent reliability rating over 74 flights, well behind ESA's Ariane 5 with a 94 percent reliability over 69 launches and America's United Launch Alliance Delta IV with 96 percent over 22 flights. Of the last ten Proton flights, three have failed. Besides the Proton the only other heavy-lift rocket to suffer any failures in its last ten flights is Russia's Zenit.



Video: Proton M failure, July 2, 2013. Credit: Spaceflight 101

Russia's long spaceflight history and the high marks it generally receives for booster and spaceflight design and engineering makes this string of failures especially odd. Other Proton failures have involved the upper stage booster, but the July 2 failure was clearly a launch stage problem and this Proton appears to have used RD-276 engines which is new for this version of the rocket. On July 18, Roscosmos said that the Proton's angular velocity sensors were installed upside-down, which ultimately caused the rocket to initiate an emergency shut down just seconds into flight.¹²⁶¹²⁷

After this most recent failure, Russia suspended Proton launches pending an investigation, which is being led by deputy head of Roscosmos, Alexander Lopatin. Russian space agency officials have been blunt as to the causes. Aging equipment, limited staff, scientific expertise and quality control, to name a

few. Some failures, like Phobos-Grunt, seem inexplicable--a critical part used in the Proton rocket upper stage (made in China) was never designed to work in outer space.¹²⁸

At a March 2013 satellite conference in Washington, DC, CEOs of four major satellite operators, Eutelsat, Intelsat, SES, and Telesat expressed concerns about the reliability of Russian launch vehicles. These firms are among the biggest private customers for launch services, of which Russia is the largest provider. “We have been disappointed... with the recent performance of the Russian launch vehicles, both the Proton and Sea Launch,” said Telesat’s Daniel Goldberg.

“Clearly, we’ve had issues with the Russian launchers,” said David McGlade, CEO of Intelsat. “I think the basic quality of the technology is good. I think maybe there’s maybe some workmanship or other issues that could have been avoided. I think they have to double down on their capabilities.”¹²⁹

It seems likely that Russia will in fact deal with these problems--its experience and skill in rocketry and spaceflight is vast--though how quickly is less clear. Nonetheless, with two Proton-Ms slated to fly ESA’s ExoMars mission in 2016, and a busy launch schedule to meet, Roscosmos has issues to address.

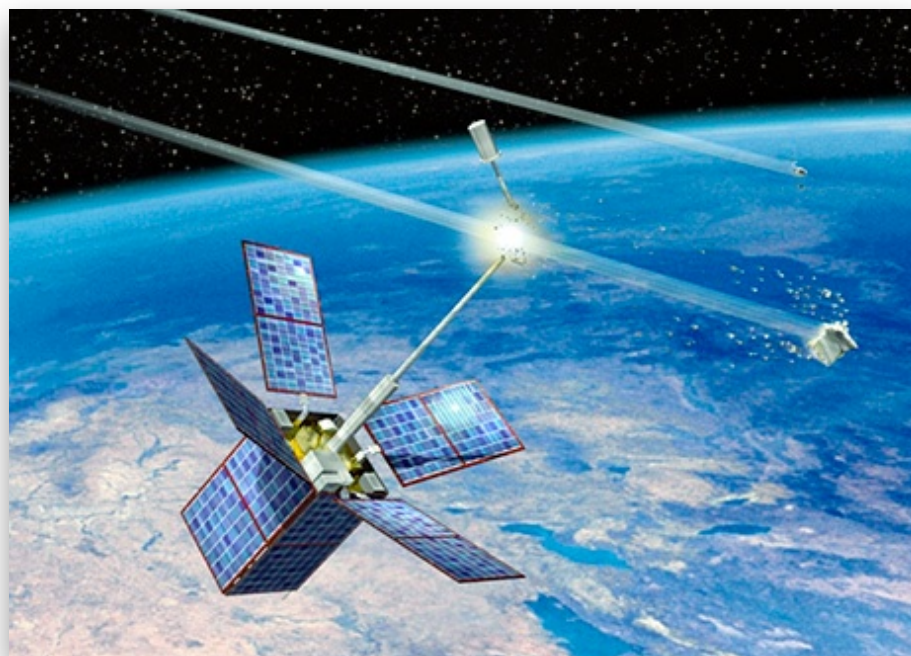
Trouble in the Debris Belt

On September 17, 2009, a Soyuz-2.1b/Fregat rocket lit the sky over the Baikonour Cosmodrome in Kasakstan. The primary payload that day was a Russian Meteor M-1 weather satellite, but piggybacking on the ride was a modest glass sphere called BLITS. A nanosatellite with a mass of barely more than 16 lbs, the Ball Lens In The Space was to spend five years on orbit acting as a laser ranging target for the International Laser Ranging Service as part of an agreement between ILRS and Roscosmos, the Russian Federal Space Agency. BLITS never reached its life expectancy. As the orb flew silently more than 500 miles above the Siberian tundra on January 22, 2013, it crossed paths with debris from China's destroyed Fengyun-1C.

The incident highlighted the fact that China's satellite-rattling had generated more than a vast new debris field in orbits already crowded with active satellites and the International Space Station; it also created a new sense of urgency among many spacefaring nations and private space interests about the

growing dangers of space junk and the need for responsible action among spacefaring nations. In terms of national security, it is perhaps a telling testament to America's military dependence on space assets that the People's Liberation Army felt obliged to demonstrate their ability to destroy them.

The BLITS event is just the latest such collision. In February 2009, Satellite Orbital Conjunction Reports Assessing Threatening Encounters in Space (SOCRATES), a weekly account provided to the satellite operator community by the Center for Space Standards and Innovation (CSSI) predicted a close approach between an active American communications satellite, Iridium 33, and a



Artist rendering of CERISE collision. Credit: National Geographic

defunct Russian communications satellite, Cosmos 2251, as they crossed orbital paths over Siberia. The approach turned out to be closer than expected, since when the time for the “close approach” arrived Iridium 33 stopped sending data to the ground. Afterwards, the US Space Surveillance Network (SSN) reported debris clouds along the orbital paths of both objects. In a sign of how imprecise situational awareness in orbit can be, the Iridium/Cosmos prediction was not even rated as the most worrisome close call in the weekly SOCRATES report.¹³⁰

The SSN had cataloged 598 pieces of debris from Iridium and 1,603 from Cosmos by June 2012. Of these, more than 300 pieces from both spacecraft had decayed from orbit at that time.¹³¹ The Iridium/Cosmos collision marks the first time two satellites are known to have collided on orbit.

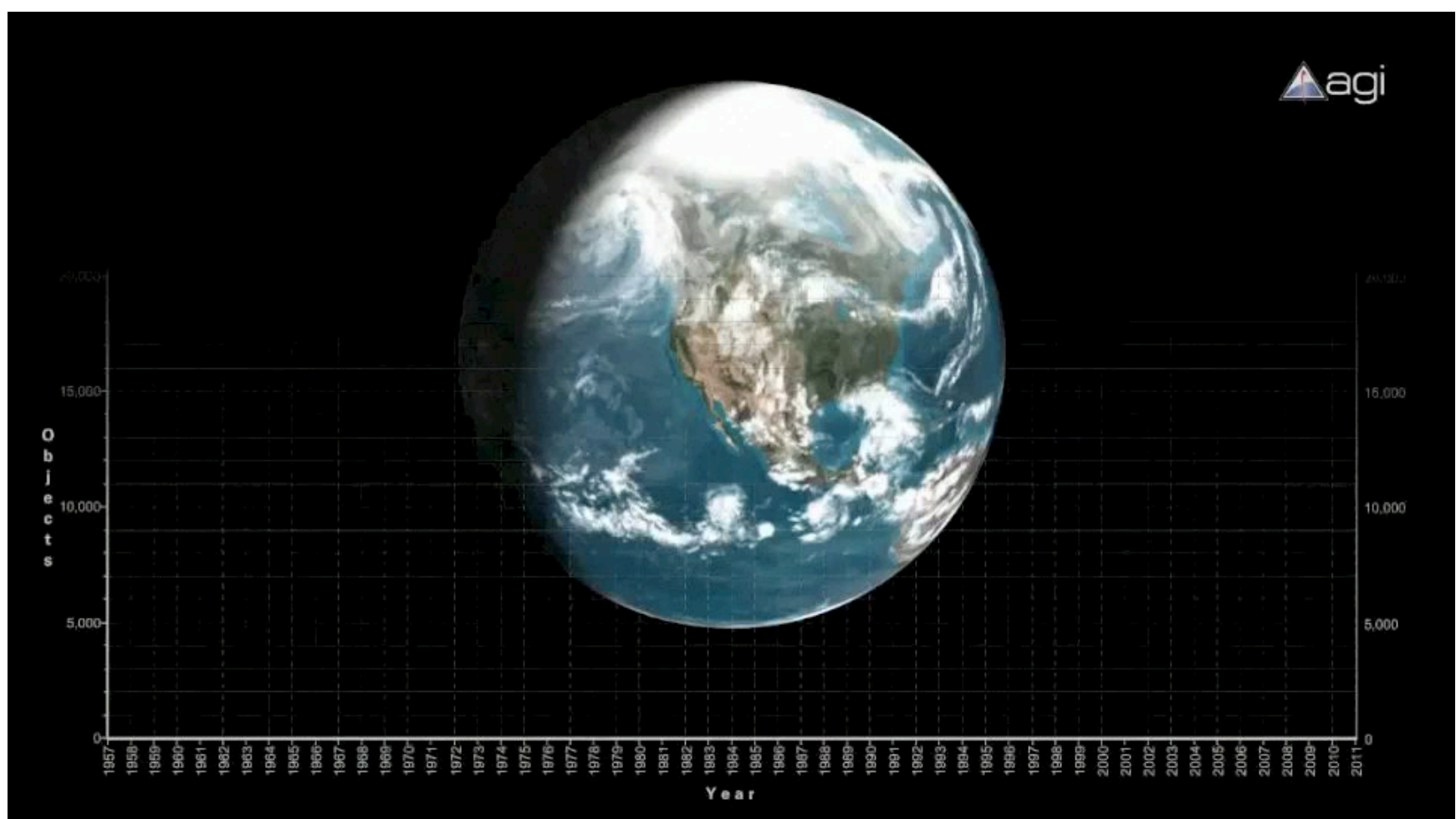
The distinction of the first collision between two man-made objects (as opposed to satellite collisions) on orbit goes to France's CERISE microsatellite and debris from an Ariane rocket booster, launched in 1986. The spent Ariane booster had exploded on orbit when residual fuel ignited after the booster had completed its mission and separated from its payload. A decade later, on July 24, 1996, debris from the Ariane rocket body slammed into CERISE at a combined speed of more than 31,000 mph.¹³² This had

been the largest debris-generating event in history until Fengyun and it remains the largest accidental event of its kind.¹³³ At the time, upper launch stages were routinely discarded on orbit, often with unused propellant onboard. A number of them simply exploded. During the 1970s and 1980s, the Soviet Union may have been the worst orbital litterbug, launching 32 radar satellites in this period--each one with nuclear materials on board to provide power.¹³⁴

Taken together, China's Fengyun ASAT test and the Iridium/Cosmos tussle seem to have focused the attention of industry and government on the growing threat posed by space debris. As of 2009, Earth orbit at all altitudes was home to some \$18 billion in commercial satellites. In the months following the February 2009 collision, Earthly insurance premiums on these assets shot up as much as twenty percent. *Newsweek*, in the wake of Iridium/Cosmos, cited industry experts predicting "that debris will now strike one of the 900 active satellites in LEO every two or three years. For the first time, junk is the single biggest risk factor to equipment in some orbits. Among the orbital threats are two former Soviet nuclear reactors."¹³⁵

The impact of space debris on operating spacecraft is accelerating. On April 1, 2011, approaching debris from Iridium/Cosmos caused the International Space Station to execute a "debris avoidance maneuver" using several booster rockets. Just four days later, Fengyun debris forced the same ISS crew to retreat into a Soyuz TMA-20 spacecraft, docked with the Station, using it as a lifeboat until the danger passed.¹³⁶ ISS crews are trained to use Soyuz in this lifeboat role. The Soyuz craft can be detached from the Station, and crews also close hatches between various modules of the Station in a collision hazard event. The lifeboat option can be chosen over maneuvering the entire Station if flight controllers conclude that there may be insufficient time to plan and execute a maneuver prior to a collision hazard. Only three times in the 13 years of human residence on the ISS has the crew retired to its Soyuz lifeboat, on March 12, 2009, June 28, 2011 and again on March 24, 2012. Each of these incidents was driven by the risk of a collision.¹³⁷ The problem is not limited to the football field-sized ISS. NASA's robotic satellites required debris avoidance maneuvers on orbit nine times in 2011.¹³⁸

Dangerous and complex as spaceflight remains, in 2013 the single greatest hazard to both manned and unmanned spacecraft in Earth orbit may very well be the risk of collision. The possibility of a tipping point in orbital debris was foreseen some time ago. NASA scientist Donald J. Kessler saw it in 1978. The *Kessler Effect*, also called *collisional cascading* or *ablation cascade* postulates that when the number of objects in orbit reaches a certain point, collisions between these objects create so many new pieces of debris that a cascading effect causes more collisions and the cycle continues to accelerate. In their paper, published by the American Geophysical Union, Kessler and his Johnson Space Center colleague Burton G. Cour-Palais said that once a tipping point was reached with regard to orbital debris, it “could render space exploration, and even the use of satellites, infeasible for many generations.”¹³⁹ NASA took Kessler seriously enough to create the Orbital Debris Program Office, with Kessler at its helm. A number of debris mitigation procedures arose from the ODPO, from trajectories that would enable upper stage boosters to fall back to Earth and burn up just after payload separation, to creating parking orbits outside the heavy traffic lanes where spent objects can be placed and tracked. For a time, these methods did seem to stabilize the situation, as the rise in the number of trackable debris objects in orbit began to



Video: Number of human-made objects in space, 1957 to present. Credit: Analytical Graphics, Inc.

flatten out. But as the 2000s progressed, the number of launches and payloads continued to increase. Then came Fengyun and the amount of orbital debris in busy traffic lanes quite literally exploded. Mitigation was no longer sufficient. Fifty years of satellites, discarded booster rockets and other space junk have been woven around the planet like a metal shroud.

US Space Command currently tracks more than 22,000 objects on orbit. Calls for a comprehensive international space traffic management system have become more urgent since Iridium/Cosmos and Fengyun. No doubt other mitigation tactics can yield results. Very small debris might even be shrugged off by more robust satellites, although at orbital velocity, 17,300 mph, any impact generates huge amounts of energy. All new satellites could be equipped with propulsion, thus enabling them to evade incoming debris as, for example, the ISS does. Both these options however add weight and cost to orbiting a satellite. Furthermore, the ability of active satellites to dodge space junk only works if we can see the debris coming. The SSN's combination of ground-based optical telescopes and radar has its limits. As Iridium/Cosmos shows, even our best technology can be off by hundreds of meters, which means that small satellites would have to carry significant amounts of fuel to steer around threatening debris.

Therefore a consensus is developing that mitigation will no longer cut through the problem. The international community must find a way to actually clean up the mess we have made on orbit. For the rest of 2013, we will get some help from the Sun.

The remainder of the year may see an increase in the uncontrolled re-entry of space debris in LEO, since this year is a "solar maximum" period of increased solar activity--a part of the Sun's normal active cycle. During these periods, the Earth's atmosphere expands, in turn creating greater atmospheric drag on objects orbiting below 550 miles. Space debris affected by this increased drag can lose altitude as much as ten times faster than during "solar minimum" periods. Without propulsion to boost their speed or orbital altitude, more of these objects can experience uncontrolled re-entry into the atmosphere.¹⁴⁰ Perturbation by the moon and solar wind can also help to drag space junk into the upper atmosphere, where it can burn up.

But uncontrolled re-entry due to solar cycles is not a plan. If the national power grid or water systems were at equivalent risk, it would be considered a serious national problem. If the power grids of the world all faced the same interlocking risk, citizens of the world would demand action.

Living in a dangerous neighborhood

On February 15, 2013, the astronomical world had its gaze fixed over the eastern Indian Ocean, off Sumatra, where Asteroid 2012 DA14 was due to give the Earth a relatively close shave, missing *terra firma* by just 17,200 miles, well inside the orbits of geostationary satellites which fly at an altitude of 22,000 miles.¹⁴¹ Asteroid 2012 DA14 measured 150 feet across and its orbit was well understood, as astronomers had been tracking it for some time. It arrived right on schedule and buzzed the planet just as predicted. The event would likely have made a good tier-two story on the local evening news, sandwiched between the weather report and sports scores. But just hours before Old Predictable whizzed past the Indian Ocean, it was upstaged by a much smaller rock with no name. Another asteroid about seventeen meters across cut a gash in the sky over the Siberian city of Chelyabinsk, Russia. It entered the Earth's atmosphere at 40,000 mph and the intense atmospheric pressures tore it apart less than fifteen miles above the surface. The resulting airburst was thirty to forty times the force of the atomic bomb exploded over Hiroshima in 1945. Characterizing the meteor and the burst it created is possible thanks to the Comprehensive Test Ban Treaty Organization (CTBTO) which operates a network of infrasound sensors around the world that detect low-frequency sound waves, looking for nuclear explosions. The Chelyabinsk meteor was in fact the largest infrasound event the CTBTO has ever recorded. More than 1,000 people were injured.¹⁴²

The Chelyabinsk event is also the largest recorded meteor strike since 1908 when an even larger object, either a meteor or perhaps a comet, exploded over a different part of Siberia, smashing 825 square miles of forest near the Tunguska River. But the size of the Chelyabinsk event is not its most worrisome characteristic. It's the fact that no one saw it coming. Subsequent investigation has revealed the likely source of the space rock, though the conclusions are not reassuring: "[it's] a typical asteroid from beyond

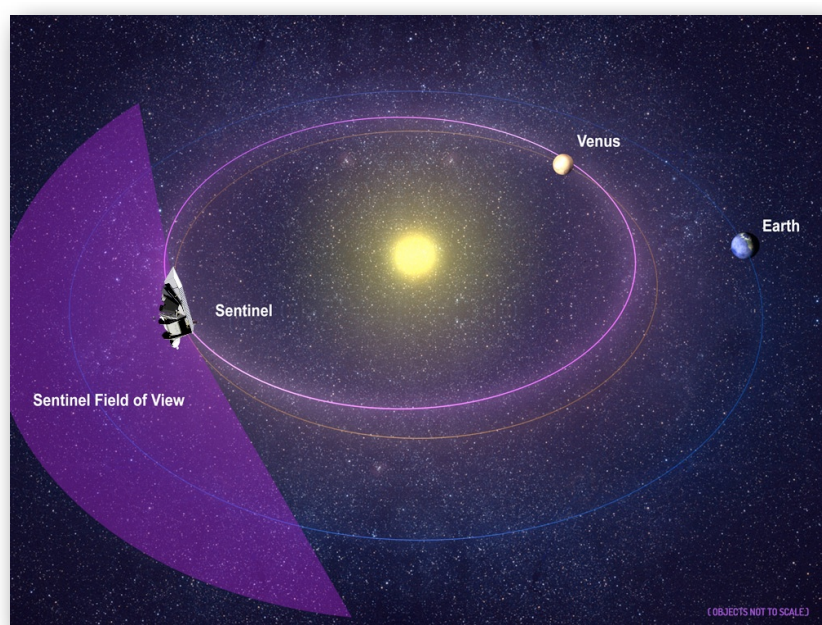
the orbit of Mars," Bill Cooke of NASA's Meteoroid Environment Office at the Marshall Space Flight Center said in a statement to Space.com. "There are millions more just like it."¹⁴³

Beyond the immediate threat to people on the ground, an unexpected, nuclear-sized airburst over any country, but especially one armed with nuclear weapons, creates broader security concerns. Had such an event suddenly lit the skies above, say, Tel Aviv, or Pyongyang, the potential implications for global security are disquieting to say the least. Dr. Joan Johnson-Freese, Professor of National Security Affairs at the Naval War College, addressed this issue before Congress in March 2013. "Given the complex political state of the world, it is clearly imperative that government officials have accurate scientific data to distinguish between meteorites and missile attacks," she said.¹⁴⁴

Also in February 2013, NASA catalogued the 10,000th near-Earth object (NEO) yet found. Many more await discovery--obviously, the Chelyabinsk meteor was on the latter list. Most primary school students are familiar with the well-supported theory that a meteor barreled into the Earth near Mexico's Yucatan peninsula 65 million years ago, playing a key role in triggering the demise of the dinosaurs. Less well known is a theory now gaining currency that an earlier, similar event may have created the conditions allowing the dinosaurs to rise in the first place, the result another mass extinction at the end of the Permian period. The mass extinction that wiped out T-Rex and his kin also took out an estimated 70 percent of all species on the planet. The Permian extinction was even more thorough, killing off 80 percent of Earth's species and evidence now suggests that this event was also sparked by a major impact. Both are relevant since they speak to the ability of an NEO impact to trigger global cataclysm.¹⁴⁵

The basic question is whether humans can improve on the performance of the dinosaurs when the time comes. Impact events are unique among natural disasters in two important respects. First, we have strong evidence that they can create planetary-level catastrophe; second, and more important, we can actually do something to prevent them provided we have sufficient lead time. Elon Musk's warning about the cycles of civilization is relevant here as well. While we are in a period of rising technology, the time is right to address the two critical components necessary to prevent a space rock from literally making humanity go the way of the dinosaurs: detection and deflection.

Of course, the dinosaurs didn't have Congress to help them out. In 1998, it charged NASA with cataloguing around 90 percent of the asteroids of a kilometer or more in diameter within ten years. NASA's Near Earth Object Observation (NEOO) Program detects, tracks and assesses Earth-approaching asteroids using assets based on the ground and in space. The space agency is also funding a new project at the University of Hawaii called Asteroid Terrestrial-Impact Alert System (ATLAS). In California, NASA's 70-meter Goldstone antenna is part of the Deep Space Network, and one of two dishes that can image asteroids using solar system radar. Any NEO findings are sent to the Minor Planet Center, paid for by NASA and operated by the Smithsonian Astrophysical Observatory for the Paris-based International Astronomical Union.



Sentinel's field of view from solar orbit. Credit: B612 Foundation

NASA takes the NEO threat seriously and international partners are also joining in on asteroid-hunting. One such effort is called NEOShield, a research program funded by Europe, Russia and the US. The ESA also launched the NEO Coordination Centre in May to better organize scientific work on the issue.¹⁴⁶ But just like the response to government plans for human exploration, the private sector sees that there's more to do in the face of such a potentially disastrous threat.

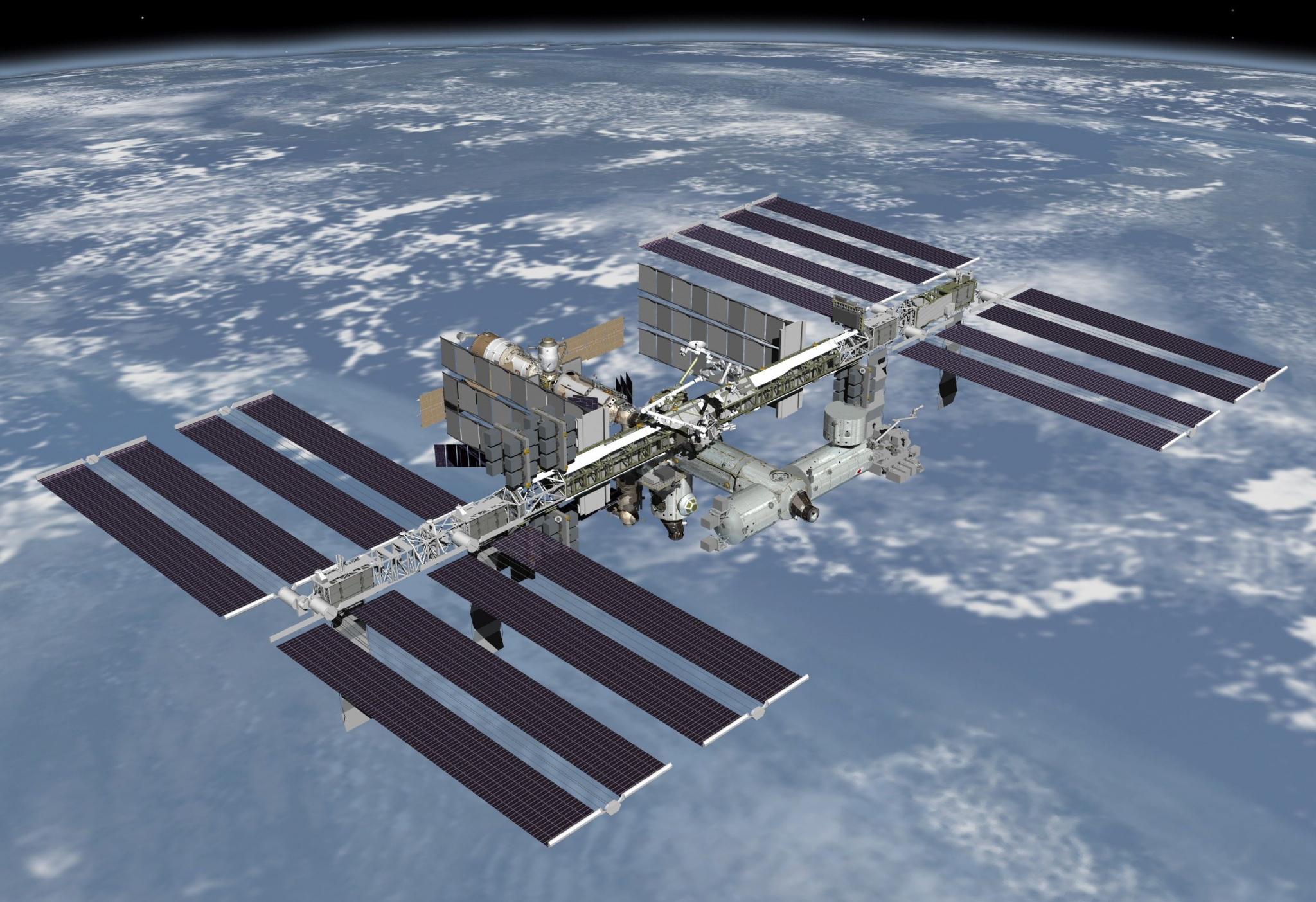
One organization, the B612 Foundation, plans to fly a spacecraft called Sentinel into a solar orbit where the Foundation says it will be 100 times more effective at finding and tracking asteroids than all the telescopes now in use combined.¹⁴⁷ B612's Dr. Lu said to Congress: "We citizens of Earth are essentially flying around the Solar System with our eyes closed. Asteroids have struck Earth before, and they will again – unless we do something about it. The probability of a 100 Megaton asteroid impact somewhere on Earth this century is about 1%. The odds of another Tunguska 5 Megaton event this century are much higher, about 30%. What if I told you there is a 30 percent chance of a random 5 megaton nuclear explosion somewhere on Earth this century? What would we do to prevent it?"¹⁴⁸

Various options exist for addressing an asteroid threat. All deal in one way or another with humanity's ability to apply some kind of force to the incoming object, which does not necessarily mean simply blowing it up, as Hollywood might prefer. "The key is not to try to destroy the thing, but to make sure it misses," says Gen. Chilton. "And that does necessarily, depending on how soon you address the problem, require tremendous amounts of force... The biggest problem is early enough detection of the threat and being able to then have the appropriate equipment at hand to be able to address it before it becomes inevitable."¹⁴⁹

The kind of solutions needed relate to how much time we have to work with. In a situation with a small amount of time and a large amount of asteroid, "applying force" with a nuclear warhead may be the only way to deflect its flightpath. More time and less rock means that a "kinetic impactor" might work, basically slamming a heavy, fast moving spacecraft into the offending rock, nudging it in a different direction. Another technology is called a "Gravity Tractor," which is being promoted by B612 and others.¹⁵⁰ The concept uses other forces of nature to our advantage. A small spacecraft, the Gravity Tractor, would intercept a troublesome rock, then fly in close formation with it. Since all objects have mass, which creates a gravitational field, the gravity created by the spacecraft itself would, over time, gently tug the space rock toward it, altering its flightpath. The course correction would be slight, but if caught early enough a small change would do the trick. Armageddon cancelled.

Operationalizing any of these alternatives will require a lot more work, but we have an advantage our predecessors lacked. "The dinosaurs didn't have a space program," B612 says.





The International Space Station.
Credit: NASA

8

CONCLUSIONS AND RECOMMENDATIONS

The United States has been rather an enthusiast of hard power since December 7, 1941. After World War II, the US became the shield of the free world against Soviet Russia, and it assumed the mantle of economic hegemony in order to stabilize the global political economy and prevent another cataclysm like the one the world had just endured. The US accomplished the latter through several means. It promoted global political organizations, like the United Nations, economic ones, like the World Trade Organization and military alliances like NATO. The US was able to accomplish all this, in effect to create a completely new order, because of its overwhelming power compared with much of the

rest of the world, which was in ruins. Although America did not literally build an empire after the war, it essentially did what empire builders have done for centuries--tried to turn its hard (military) power into soft power. That is to say, the US, powerful as it was, could not literally police the entire world. Even if it could, as Rousseau said: "The strongest is never strong enough always to be the master unless he transforms strength into right."¹⁵¹ The British did this pretty well, effectively controlling the largest empire the world had ever seen with relatively few troops. So in the post-war period, the creation of a web of international organizations and means of international relations served to transform American hard power into the soft power of legitimacy.¹⁵² That's one reason why America won the Cold War--it transformed its considerable hard power into soft power far more effectively than the Soviet Union did. Where America's soft power succeeded it was promulgated by leading rather than commanding. This is certainly true in the realm of space.

On orbit, as on land, air and sea, America's hard power is considerable--but in space, hard power is different. It does not, for example, consist of a fleet of space tanks massing in LEO. On the military side, it is a complement to America's Earthly raw military strength: reliable and accurate missiles (some of which would traverse space if ever used), along with a constellation of GPS, reconnaissance, early warning and other support assets. On the civil side, hard power consists of a reliable and powerful fleet of launch vehicles and spacecraft, spaceports and other ground support assets, a strong industrial base and deep operational experience in the most unforgiving and hostile environment known to humankind. What is the same, whether on land, sea, air or space is that the physical assets of hard power are ineffective and insufficient unless it is commonly understood that the political will exists to support them, maintain them, and use them if necessary. The pursuit of a space arms treaty by China and Russia is testimony the enduring strength of US hard power in space. US soft power has come in the complex political decisions we have reviewed that led to truly extraordinary achievements, specifically Apollo, the Shuttle and the station--all feats that no other nation had achieved. "The U.S. traditionally has lead by doing," says David Patterson, Managing Partner of Castlebridge Keep. "Our successes have prompted others to team with us or to collaborate in other ways. The U.S. has been successful when it has

established clear, achievable goals, a workable plan to achieve those goals than then funded and executed to the plan.”¹⁵³

On the ground, the global organizations the US has either created or promoted in the post-war period (the UN, World Trade Organization, NATO, etc.) have gained the best kind of legitimacy of all-- participation. This too has continued in space, with the US immediately bringing the world into the discussions that created COPUOS and thus extending its soft power into the final frontier.

Transforming those hard power assets into soft power involves using them in pursuit of a clear and compelling plan to tackle threats, explore our solar system and achieve new heights for humanity with meaningful international partnerships. Just as hard and soft power are symbiotic on the ground, so they are in space. This seems to be a point the Obama Administration missed when it scrapped Constellation and wanted to forego development of the heavy-lift SLS as well. If the president chose to “cancel” the US Army, it seems likely that US soft power would also decline. Similarly, without the tools of hard power in civil space such as a heavy-lift vehicle capable of taking people to new destinations, soft power is harder to exercise.

The challenges humanity faces in space lend themselves to international effort, which always requires international leadership. The threat of orbital debris is significant and menaces the larger spacefaring nations disproportionately. We have not yet reached Dr. Kessler’s tipping point since space remains accessible and useable. Mitigation techniques have been effective in slowing the rate of growth, but the problem does continue to grow. Earth orbit is home to critical national infrastructure and allowing the current hazards of debris to remain or grow would threaten this infrastructure. The threat from NEOs may or may not be more immediate than orbital debris, but the threat level could be extraordinary, even existential, and it is shared by everyone. The fact is that we have the collective ability to build systems that can protect our planet from the regional or global destruction which could result from a comet or asteroid, but the nations of the world have never comprehensively marshaled our resources and creativity toward the task. Failing to do so would be the most horrendous negligence.

These are daunting challenges to be sure, but there is hope in stirring leadership, technical ability and experience. “The world has done this before. It has addressed large global problems that affect everybody, and so it can be done, but nations won’t do it until they perceive that it’s in their best interests to do it.” Gen. Chilton said.¹⁵⁴

An international leader will have to commit to executing a number of elements well. The ability to induce other nations to constrain their tendencies to “free ride” on the efforts of others and instead to participate in global solutions to these problems will be important for success. This concept has a model on the ground with regard to promoting international cooperation, economic expansion and improved standards of living, while mitigating the threat of destabilization and conflict. It’s called hegemonic stability theory (HST), and it postulates that only a hegemon--that is an actor within the system who is sufficiently powerful to provide important collective functions for the global political economy and then willing to bear the costs of providing them--can stabilize the system, particularly during periods of economic shock.¹⁵⁵ This is, in effect, the role the United States has played on the ground since World War II through the exercise of its soft power, creating the rules of the military, political and economic game in the free world that knit political economies together, managed risk and promoted trade across borders. After the Cold War ended, even most East Bloc countries were integrated into this global system.

As the list of spacefaring nations continues to grow the orbital debris risk grows, as does the problem of crowded orbits and bandwidth issues. This situation creates a greater likelihood of instability and disarray where cooperative action could unravel and narrow national interests ascend. The HST analogy is limited but instructive. In space, the most significant function for the collective good is space situational awareness (SSA). As noted previously, this is inadequate, both in Earth orbit and in the general Earth neighborhood. The most complete catalogue of space objects, however, is available through the United States Space Surveillance Network (SSN), which is part of the United States Strategic Command. SSN provides space situational awareness data for a number of functions. It predicts the location, timing and path of re-entering objects, detects new man-made objects in space, and catalogues and differentiates man-made objects. Importantly, SSN also works to prevent re-entering objects from

triggering the missile attack warning sensors in the US and other countries, since re-entering objects look like missiles on radar. The SSN system has gaps and it is not perfect. Objects smaller than a softball, for example, are too small to see with current technology. Even so, much of the world relies on SSN for their own space situational awareness. Spacefaring powers, including China, reach out to SSN before a launch, to make sure they have a clear path to orbit.¹⁵⁶ This is a vital “collective good” provided to users worldwide but built and paid for by the US military, similar in that sense to GPS.

Other important collective functions in space include the ability to provide reliable access, especially to LEO and geosynchronous orbits, for both manned and unmanned flights, and the industrial strength to push technology forward. The United States currently provides only some of these, SSA, access for unmanned spacecraft and industrial strength. The Russian Federation, Europe, China, Japan and India all have unmanned launch capabilities, along with a few other countries. Russia, as noted earlier, is having reliability issues with its launch vehicles but it remains a dominant provider for unmanned access to space. Russia and China both have manned spaceflight too, though Russia’s is confined to ISS flights and China has yet to orbit an international crew.

Post-Apollo US manned spaceflight has demonstrated one truism about the space age: political inertia creates far greater drag on human spaceflight than does gravity. Humanity is in space to stay (barring cataclysm), but its future will depend on ground-based leadership as much as technical advancement. America has first pointed toward and then either accomplished or led an international partnership to accomplish many of humanity’s important milestones in space: manned exploration of another world with Apollo, reusable spacecraft with the Shuttle, a permanently manned city in space with the ISS, robust exploration of the solar system and beyond with Viking, the Voyagers, Galileo, Messenger, Kepler, Spitzer, Pathfinder, Spirit, Opportunity, Curiosity (the list goes on). This remarkable history as a leader and responsible actor in space, along with US economic and technological strength and its hard space power assets (assuming SLS/Orion comes on line) all recommend it to play a leading role, and indeed it is the nation best suited to organize the world relatively quickly to meet the challenges we face. Russia and China are both strong powers. Russia is a near-peer to the US in space overall and would be the most obvious alternative for strong international leadership in space. It has manned spaceflight--indeed, the



China's Shenzhou 9 rocket launches from the Jiuquan Satellite Launch Center on June 16, 2012. Credit: AP Photo/Ng Han Guan

Russians invented it--and a robust family of boosters and ground facilities along with a long and storied history of achievement in space. But recent technical problems seem to bespeak larger issues with its technical base and science community. The Russian government seems to take Roscosmos' technical challenges seriously, but the underlying quality control issues they reflect are cause for real concern, so effectively addressing them is another matter. Moreover, the government's recent controversial move to reorganize the Russian Academy of Sciences creates even more questions, at least in the near term.

China is developing quickly on many fronts. It is and will be an important player but hasn't the depth of experience in space or the proven ability to work within, let alone lead, a major international effort, such as the ISS family. It also carries the albatross of Fengyun around its neck. Although its rise is impossible to ignore (although Congress is certainly doing its best), China--the government, the Communist Party and the PLA--still has work to do to prove itself a responsible actor before it can legitimately assume a leadership role. Europe hasn't the resources to lead global efforts in space and its political and

policymaking complexities would also hamper such an effort. All these things, along with the need to organize global action relatively quickly, recommend the United States for reasserting the leadership role necessary to address the international challenges we face in space security and spaceflight, though not just by default. America's technical and economic capacities are vast and its history of leading international coalitions, building international structures and providing collective goods to nurture and sustain global systems have no peer. To lead global action in space going forward, however, it will need to get its act together.

After exploring the decisions that went into the major elements of US manned spaceflight a distinction presents itself. Project Apollo was an answer to a specific, burning question asked by President Kennedy, "Is there someplace we can catch up?" The Shuttle (Nixon) and the space station (Reagan) answered no such burning presidential questions. Instead, they both seemed effective ways to extend US leadership and soft power, and to be the next logical steps in human spaceflight. Both the Shuttle and the station, revolutionary in their own ways, also appeared to be essential steps on the road to the obvious, ultimate destination for humans: Mars. The Shuttle was seen as an airliner to service the space station, which it also ended up helping to build. The station itself was critical in terms of understanding how spending months, even years in space affects humans and machines, knowledge critical in planning any manned mission to Mars. The moon missions lasted just ten days. Gemini 7 spent 13 days in orbit in 1965 to prove that people and human-rated machines could survive long enough to get to the moon and back. The space station needed to fill the same role for much longer duration missions. But it wouldn't have been built without decisive American leadership and strong international participation. The demonstrably successful ISS model is surely one to build upon.

Today, Mars remains the outlying goal, but, as before, no burning presidential question underlies any of the manned spaceflight options being pursued by the US. SLS/Orion are systems that provide important capabilities, but the plan of exploration attached to them is vague, uninspiring and poorly communicated. The US administration, perhaps consumed by the Great Recession and one partisan impasse after another in Washington, appears to have little interest in or appetite for a meaningful space policy.

In addition, the gap between what NASA is asked to do and the money the space agency is allocated to do it must narrow and some measure of certainty must be built into its long-term planning. Space systems and operations take time to design, test and build. Constant budget uncertainty and policy zig-zags waste both time and money. With regard to the problems of orbital debris and planetary defense, we really do not know how much time we have--ten years, a hundred or a thousand. If we plan for a thousand but only have ten, we're in trouble. The same is true for becoming a multi-planet civilization. The ruins of the Colosseum or Rome's massive aqueducts are a reminder that technology (indeed, civilization) does not necessarily trend in one direction indefinitely. While we have the capacity to send people out into the solar system, we should.

The US needs to set realistic goals in terms of technology, politics and funding. As part of this process, US space policy makers should look at alternative proposals, like those for a US Department of Space, for organizing the nation's space functions. To consider such changes, realistic and meaningful benefits in cost effectiveness and performance would have to be identified.

At the height of Apollo, NASA's budget was about 4.5 percent of all federal spending; today it is 0.5 percent. Writing in 2003, the Columbia Accident Investigation Board echoed two common themes that can be found among many space policy observers since Apollo, first that "Continued U.S. leadership in space is an important national objective;" and second "That leadership depends on a willingness to pay the costs of achieving it." But the halcyon days of Apollo will not be coming back. The incremental approach to planning and budgeting is something NASA will have to live with. It did this successfully with the station. Even if the ambitions of the final project were scaled back, it is now a city in space. The same is somewhat true of the Shuttle, though the the orbiters were America's only ticket to ride for 30 years so it would have been problematic to cancel the program without a replacement--a fact the US now knows all too well.

Looking at the challenges we face and the resources we have, a more realistic floor should be created for a consequential national space program, including manned spaceflight. In 2013, a space budget at 4 percent of GDP makes no sense (though that could certainly change quickly if a rock with our name on it

wandered into view), but the administration and the Congress should find a better way to budget for long-term space operations. Since the US spends as much as the rest of the world combined on space, doing so also gives the US greater moral authority to induce greater spending, if incremental, from its partners.

While putting its own house in order, the US needs to work with its allies and partners to communicate clearly what is known about the threats we face and the opportunities we have as a way of clearly defining national and international interests. Perceived interest is a critical element for building political support, especially in a democracy but even in more authoritarian states. As we have seen, the threats and opportunities are real and they require a properly funded, well led, international space program. Today, “selling” a space program to skeptical and frugal taxpayers no longer requires Dr. Stuhlinger’s prospective hope of gains to be won, though they certainly still exist. There is always more knowledge to be gained by exploration, experimentation and innovation. Now however there is an even more potent, and alarmingly real, argument to be made for investments in space based on fear of loss that goes well beyond pure science. The machines we now fly through space have become inextricably linked with many aspects of modern life on land, sea and air. They have made us safer, better fed and immeasurably more knowledgeable about our own world, our neighbors in the solar system and the great expanse beyond. More directly, hundreds of millions, perhaps billions of people already rely on space-based assets in one way or another for weather forecasting, communications, financial transactions, the food they eat and the timely arrival of other products that are a part of daily life. A failure to maintain and protect the systems in place and to plan for the next generation of robotic and human spacecraft puts these assets at greater risk. Losing our capabilities in space means losses on the ground as well. Moreover, we risk losing our civilization itself--a risk that may be more obvious to the general public due to the events of 2013 (at least for a time). While hopefully the unwelcome “scare tactics” of unexpected asteroids won’t continue, the public needs to be educated on the nature of the threat, and perhaps more importantly on how little we actually know about the nature of the threat. If the United States understood a potentially lethal Earthly foe as little as we understand the NEO threat, it might well be considered a national emergency. American politics commonly demonstrates that voters are often more

motivated by fear of loss than hope of gain. Therefore, failing to account for both gain and loss and then to communicate these properly to the public endangers the entire future of humanity's enterprise in space and perhaps on the ground too.

After getting the public's attention, a Comprehensive Outer Space Strategy should be created in collaboration with America's allies and partners. The ISS partnership, together with China and perhaps India, makes the most sense as a mechanism for this discussion to take place. The ISS partners have by now a long history of political, technical and operational experience working together in space. Robert Freitag's prescience in the early 1980s while trying to create an international partnership to build the space station was correct: "Whether it's a ballistic missile kind of thing, or saving the environment, or I don't know what, sometime we're going to have to work together on a real important thing like a large program."¹⁵⁷ Now, we have more than one "real important thing" to work on, and the ISS partnership offers a strong platform on which to build. The addition of China and India to these discussions makes sense not only in that they represent a significant portion of humanity but also because they are both rising space powers, though China far more than India. To include China, policy makers in Washington will have to eschew their parochialism and nationalism. US pursuit of a new "space race" with China would be a grave mistake, but the global competition between the two powers is unmistakably taking shape and cooperation in space could serve to build trust and confidence among the two, along with other benefits. China's growing capabilities and ambitions mean that it will eventually become a fully integrated part of the international space community, and probably sooner rather than later. It can do so on its own terms through agreements and coalitions of its own choosing, or by being invited by the United States into existing international constructs, like the ISS family, that are legitimate, broad coalitions and fundamentally cast by the US. Building upon America's soft power in space is best advanced by the latter, as is a program to deal with the threats the world faces in space.

Unfortunately, the ISS partners currently plan to de-orbit the station in 2020 or thereabouts. China has said it wants to orbit its own space station at that time, and Russia is considering using the Russian-built parts of the ISS as the core of a new Russian space station after 2020. For the international community to just pursue their own national projects, for the ISS partnership to simply melt away, with

no follow-on project would truly be tragic. It would be a waste of much experience and successful international collaboration. Russia and China both have the capability to orbit their own space stations, but if they were to incur the extraordinary expense of doing so and spurn an ongoing international partnership in space due to a lack of leadership, that would be even more tragic. The United States must step forward decisively to keep the ISS partners working together, thinking together, planning together to address the problems we face, focus the world's resources and nurture international relations.

In tandem with this effort, the US and Europe should actively pursue broad negotiations to adopt a Code of Conduct for Outer Space Activities using as a starting point the draft Code submitted by the Council of the European Union. Technical issues and definitions will be complicated to negotiate with China, Russia and the other BRICs, but pursuing the Code as part of a package of activities that includes the expansion of the ISS partnership would demonstrate the sincerity of the West.

Once the extended ISS family is assembled, it should create the Comprehensive Outer Space Strategy to integrate national and commercial capabilities in order to forward eight goals:

1. Build the ISS partnership (with room for further growth) into a permanent mechanism for focusing global resources, planning and action in space;
2. Create greater situational awareness in space, both in Earth orbit and in our broader neighborhood with regard to NEOs;
3. Reduce and manage the orbital debris threat to sustain a safe and secure space environment for the spacecraft upon which we increasingly depend for both military and civilian use;
4. Build a robust planetary defense from NEOs, with plans and systems in place for different scenarios with differing lead-times;
5. Use space-related activities as a means of creating greater security and prosperity, international understanding and cooperation on the ground;
6. Advance human and robotic exploration of the solar system, greater knowledge in the sciences and thus the amalgamation of human understanding;

7. Become a multi-planet civilization; and
8. Build sustained public support for these activities.

The strategy should be built out into a coherent plan, with a realistic assessment of strategic and tactical assets each partner can bring, specific and realistic budgets, timetables and actual destinations as opposed to the nebulous-- “somewhere in the vicinity of Mars”--destinations the US is currently pursuing. Leveraging the resources and aspirations of many nations will allow us to assemble the money, the imagination and the talent needed to accomplish revolutionary things, as with the ISS. It will also serve the interests of international understanding, peace and stability on the ground. By choosing to create critical national and international infrastructure on Earth orbit, we have indeed “tossed our caps over the wall of space.” By developing the tools to understand the devastating nature of natural threats that confront us from space, we have indeed assumed the obligation to manage the situation more skillfully than the dinosaurs.

Building an effective global set of properly interlocking national space policies to meet the world’s challenges is less about rockets and spacecraft, and more about leadership and determination. Such leadership must result in a realistic and effective plan supported by the political, technical and monetary resources necessary to accomplish it over a sustained period of time. Canada, Europe, Japan, Russia and the United States have all done this with the International Space Station. To achieve bigger and even more pressing goals, they will have to go a step further, and the United States must lead this effort with some urgency. They must grow the ISS family and better communicate to their peoples both the risks and rewards that await us in space. The last person to accomplish all these things together was John F. Kennedy.



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